FINAL REPORT:

Land Use / Land Cover Interpretation and Analysis for Three National Monuments

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EXECUTIVE SUMMARY

This project integrates remote sensing and landscape metrics to quantify land use/land cover change at three National Park Service units. These include (a) Effigy Mounds National Monument (EFMO), Iowa; (b) Pipestone National Monument (PIPE), Minnesota; and (c) Wilson's Creek National Battlefield, Missouri. Aerial photography spanning a period of six decades, IKONOS pan-sharpened (1x1 m) data, and input from the Park Service were used to develop land cover classification maps for the 1940s, 1960s, and 1990s. A post-classification algorithm was applied to derive land cover changes, and landscape metrics were used to analyze specific habitat classes.

At EFMO, overall changes in natural vegetation between 1940s - 1990s showed interchangeable shifts whereby the canopies of some areas of deciduous forests and bottomland woodlands thinned out, whereas others transited from croplands in the 1940s to full growth forest in the 1990s. Similar patterns were observed for cropland and pasture, where the total area of cropland declined while that of pasture increased, albeit with a decline in the number of patches. Land cover changes around EFMO reflect the impacts of management decisions made in response to shifts in agricultural and economic policy while, within EFMO the areas of "natural" vegetation are well maintained and devoid of any significant human activity.

The majority of land use at the PIPE study area is dominated by agriculture. Pasture and cropland make up most of the areas used for production and an exchange between the two classes can occur as a result of several factors. Soil conservation goals, changes in economic subsidies for grain crops, changes in profit margins for land owners that can be realized in other categories of commodities are things farmers must consider when deciding how to get the most return from the land assets they control. From an

overall perspective 1940s -1990s, there was an increase in urbanization through infrastructure development, commercial, and residential. A general decline in pasture areas was accompanied by increases in cropland indicating changes in agricultural practices in the region

At WICR landscape patterns revealed that "natural" land cover classes (e.g., oak/hickory forest) have been affected by human influences through the regularization of their boundaries. Major landscape changes around WICR have been due to the exponential urban development and residential growth in cities near the park (NPS, 2002). Recent growth in the Springfield metropolitan area has changed the character of land use patterns in the suburban areas of Springfield, Battlefield and Republic. Large agricultural tracts increasingly are being subdivided into 10-acre residential home sites; as a result, the land area of Springfield has grown significantly. In 1961 WICR was approximately 10 miles from Springfield city limits. Now, however, metropolitan Springfield is as close as five miles from the park, and this changing land use pattern is visible and audible from within the park boundaries. For example, transportation improvements to serve this growing suburban population are bringing higher traffic volumes and associated noise to county road ZZ and Farm Rd. 182, which respectively border the western and northern boundaries of the park.

Unlike typical change detection procedures, this project focused on integrating the change detection results with landscape metrics. By incorporating input from PC LTEM personnel and local residents, a detailed and thorough land cover classification scheme was produced. The post classification change detection method provided information on the “from-to” conversion between land covers, while the landscape metrics explained the impact of human influence in and around the study area

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1. INTRODUCTION

In 1994, the United States National Park Service (NPS) established the Prairie Cluster Long Term Ecological Monitoring (LTEM) Program as one of the eleven prototypes to develop natural resource monitoring within NPS. The LTEM program currently monitors the status and trends of natural resources in six parks located in four Midwestern states. A primary focus of the program is to develop and implement monitoring protocols for resources affected by active management and/or external park threats. The NPS desires a technique to measure past and future trends in adjacent land use to provide a regional context for trends observed within park boundaries.

Park ecosystems are affected by changing land use outside park boundaries as well as internal management actions. For many parks, agricultural, residential and industrial developments are prominent adjacent land uses. Other parks are experiencing rapid development at their boundaries. Due to their size, small parks are particularly susceptible to outside influences such as degradation of water quality, loss of wildlife corridors and colonization sources, invasion of exotic species, and visual intrusions. In addition to the loss of adjacent prairie habitat, park ecosystems are also affected indirectly by increasing fragmentation and isolation of remnant grasslands. The effects of fragmentation are threefold. First, many species may require large, intact parcels of grassland for survival and reproduction, and as remnants decrease in size, these area-sensitive species are progressively extirpated locally (Herkert, 1994). Second, as remnants become more isolated, the probability of colonization/re-colonization of a patch decreases with distance from another patch (Kaufman and Kaufman, 1996). Third, populations in isolated patches suffer from genetic inbreeding and accelerated rates of genetic drift (Benedict *et al.*, 1996).

Increased fragmentation of natural areas will also have a negative effect on threatened and endangered species, grassland birds, and butterfly assemblages found within the park, as well as contribute to proliferation of exotic invasive species. The goal of NPS is to develop methods for providing information to support natural resource management decisions that will protect and improve the sustainability of the populations of plant and animal communities that are representative of the period of significance as specified in each park's enabling legislation (typically to a time period pre-dating the influence of human settlement. By quantifying and documenting changing land use patterns within and adjacent to the parks, important ancillary information can be provided for monitoring the stability of terrestrial and aquatic prairie ecosystems.

1.1. Objectives

The overall objective of this project was to map the land use/land cover change in three Midwestern states over a period of 60 years, and analyze possible anthropogenic impacts based on image interpretation and landscape metrics. Specific objectives include:

- Spatial identification and quantitative assessment of land use changes from natural or semi-natural vegetation types to non-native vegetation over a period of 60 years.
- Examine potential causes of these changes.
- Analyze landscape metrics for select land cover types.

2. STUDY AREAS

2.1. Effigy Mounds National Monument

Northeastern Iowa represents an environment of overlapping plant ecotypes. The eastern hardwood forests merging with the grasslands of the west have created a mosaic of forests, savannas, and prairie. Early survey records reveal that northeastern Iowa was a heavily forested region interspersed with oak savannas and prairie openings. The prairie openings extended into the forest area along ridge tops with smaller openings being found on south facing bluff edges maintained by shallow soil, higher temperatures and drier conditions. Today, the steep hillsides are dominated by climax stands of maple-basswood and oak-hickory vegetation communities with small goat prairies found on drier sites. Within the floodplains of the Mississippi and Yellow Rivers, Paint Creek, and Bloody Run Creek, lie nearly 100 acres of ponds and lakes making for valuable wetland resources.

The Effigy Mounds National Monument (EFMO) north unit covers an area of 2,526 acres and is located in this driftless (non-glaciated) area of northeastern Iowa (Figure 2-1). It lies in a geologically unique area of erosional topography drained by an intricate system of rivers and streams. Erosional forces have cut through a plain leaving high divides and precipitous bluffs towering up to 500 feet above adjacent waterways. Nearly 1,200 acres of the monument are forested by rapidly maturing stands of mixed hardwood species, while approximately 80 acres of old field openings are being managed as recovering or restored prairie. An area of about 20 acres has been treated as part of an oak grove or savanna restoration project for the restoration of nearly 50 acres of oak savanna.

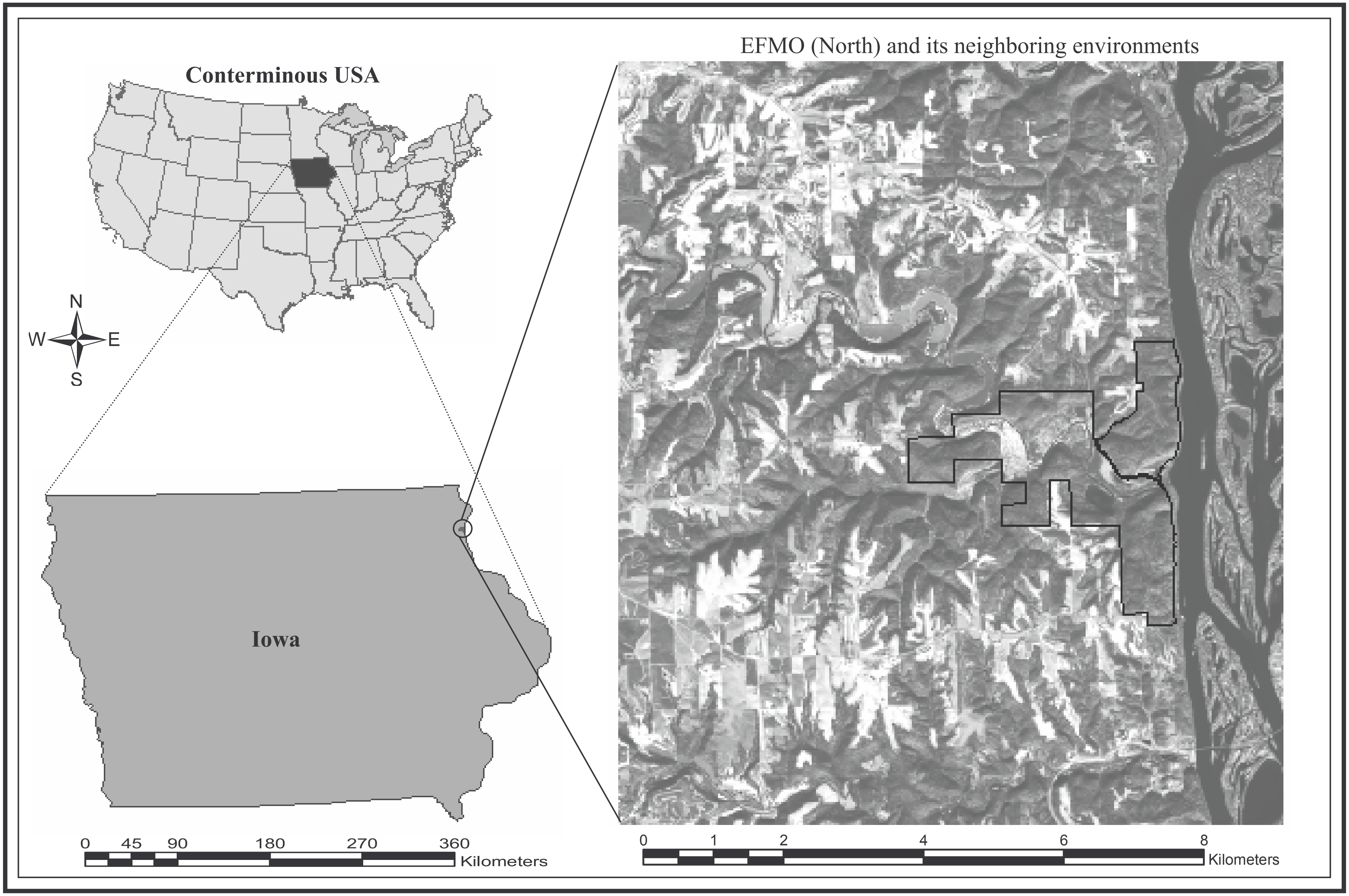


Figure 2-1: Location of Effigy Mounds National Monument, Iowa in the conterminous United States. The IKONOS image dated 18 October 2001 shows the entire study area with the park boundary delineated.

The monument represents an important link in a complex of protected areas that preserve many of the values characteristic of this region. Much of the nearby Mississippi River bank and island area is protected by the Upper Mississippi River National Wildlife and Fish Refuge, a 261-mile-long preserve that extends from Wabasha, Minnesota, to Rock Island, Illinois. Situated between the currently developed EFMO monument units and the south unit (Sny Magill) is Pikes Peak State Park, which preserves several effigy mounds, as well as bluff tops much like those of the monument. Sny Magill, about 11 miles south of the headquarters area, is in the Mississippi River bottom (Figure 2-2) and contains the largest extant concentration of Indian mounds (about 100) in the country. Management efforts for the monument focus on the protection and preservation of the burial mounds, control of exotic species, and restoration of the cultural landscape associated with the mound building era.

2.2. Pipestone National Monument (PIPE)

Pipestone National Monument is located in Pipestone, MN in the southwestern portion of the state (Figure 2-3) was establish in 1937 to manage the Catlinite (pipestone) quarries in a way that provides all Native Americans with free access to quarry the Catlinite and to fashion and carve from it the articles relating to their cultures. The Monument seeks to preserve and manage the ethnological, historical, archeological, and geological resources in their natural tallgrass prairie environment. Pipestone is approximately 283 acres and is located on slightly sloping land in a shallow glacial valley. The natural resource base of the Monument consists of prairie and grassland.

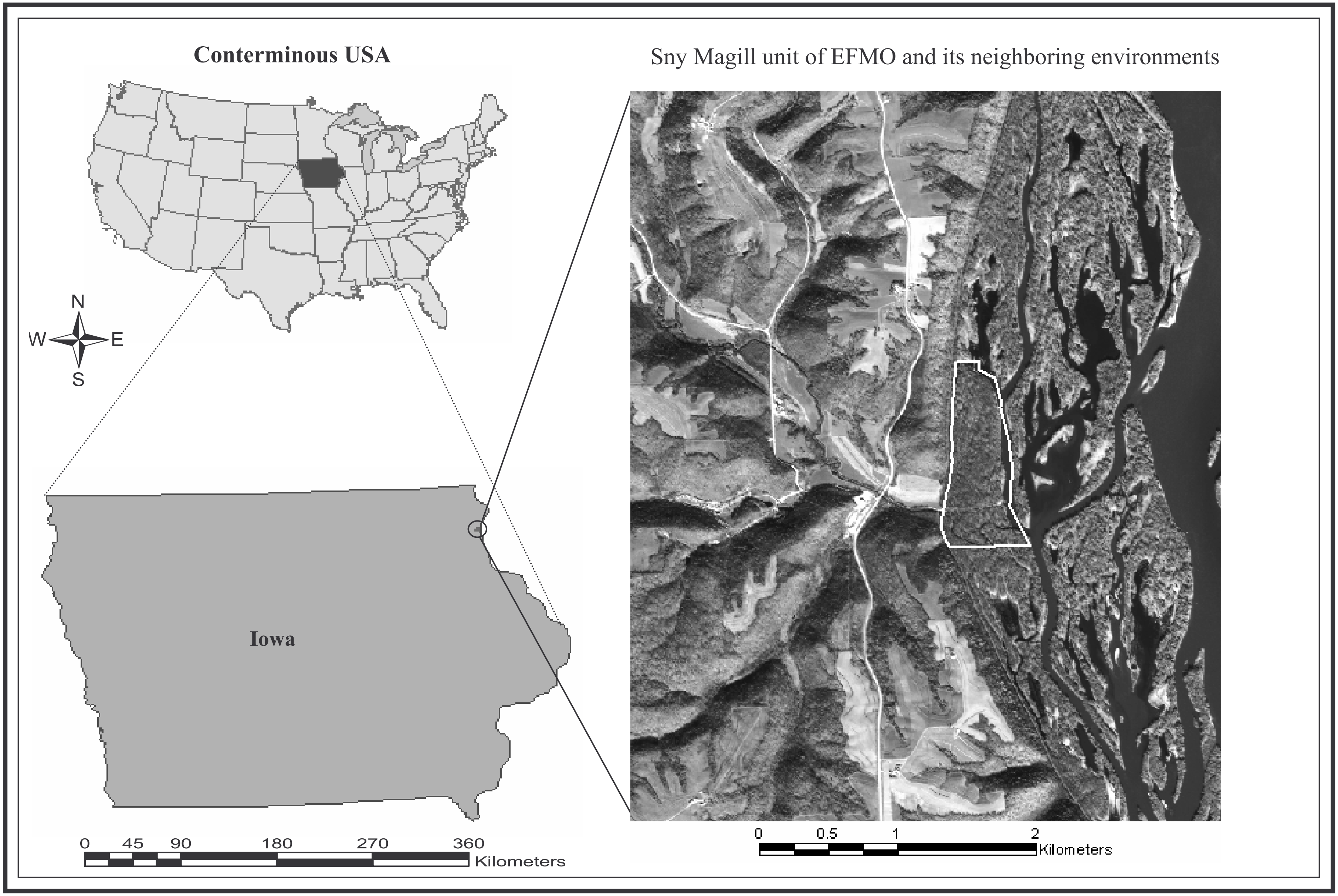


Figure 2-2: Location of Sny Magill unit of EFMO, Iowa in the conterminous United States. The IKONOS image dated 18 October 2001 shows the entire study area with the park boundary delineated.

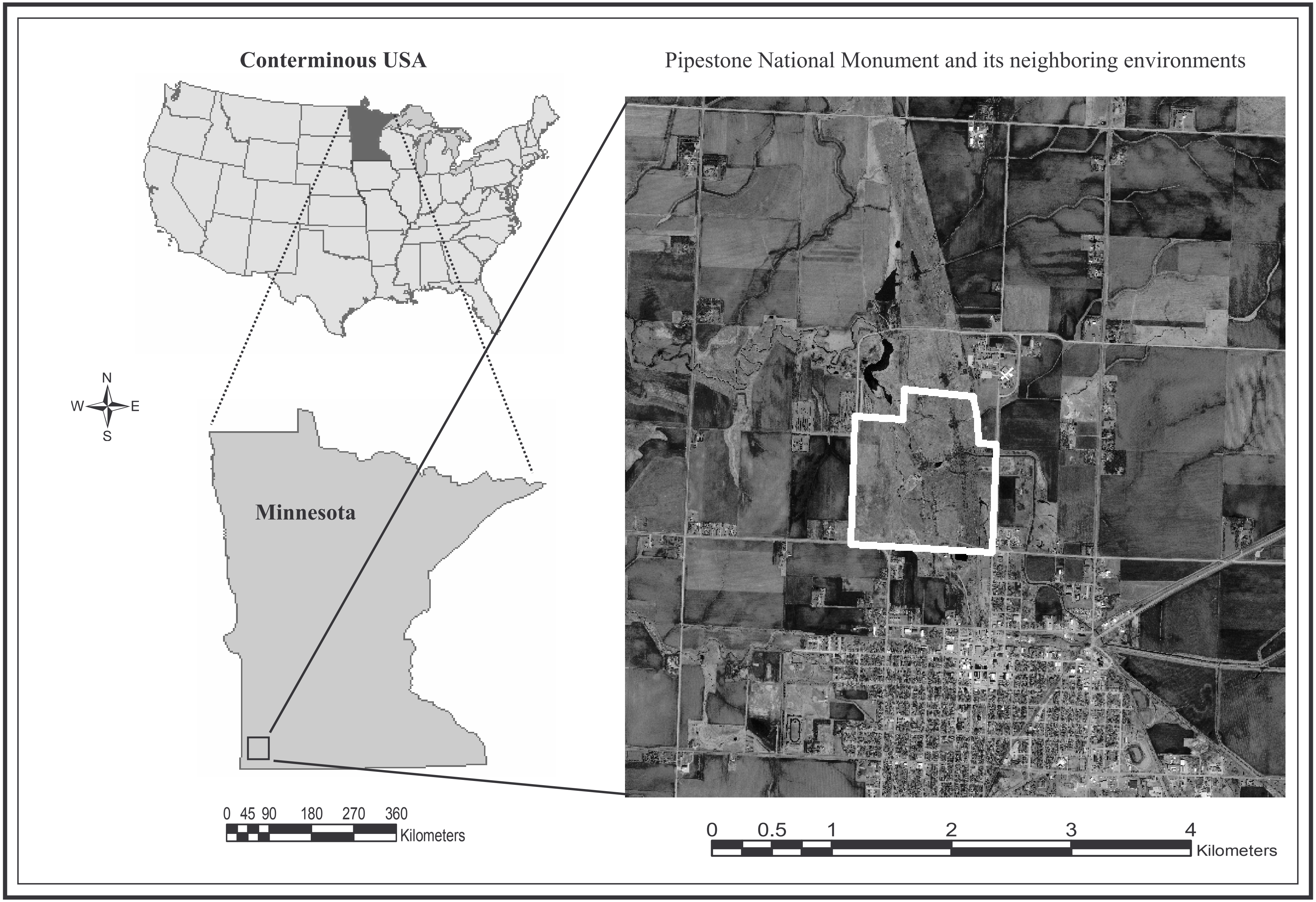


Figure 2-3: Location Pipestone National Monument, Minnesota in the conterminous United States. The IKONOS image dated 17 April 2001 shows the entire study area with the park boundary delineated.

Vegetation consists of virgin native prairie, restored prairie, degraded prairie, old field communities, and oak savanna. The prairie is bisected in a north – south line by a 15-foot high Sioux quartzite outcrop in the eastern quarter and by the pipestone quarry line near the middle of the Monument. The prairie located along the Sioux quartzite outcrop is considered a significant natural resource to the Monument. The Nature Conservancy has designated this prairie type as "endangered throughout its range", and sites Pipestone as one of the few intact examples of this rare community type. Numerous rare plant species occur through out this habitat. Another significant resource is Pipestone Creek, which flows over the Sioux Quartzite outcrop forming Winnewissa Falls. Above the falls the creek has been channelized by blasting and dredging and now flows well below the original creek bed. Below the falls the creek retains some of its original characteristics. Pipestone Creek flows through Lake Hiawatha and eventually out the north boundary of the Monument into Indian Lake and the Pipestone Wildlife Management Area. The wildlife management area is owned by the United States Fish and Wildlife Service and managed by the Minnesota Department of Natural Resources Wildlife Division. One population of the federally threatened western prairie fringed orchid occurs in the native prairie and the federally threatened Topeka shiner occurs in Pipestone Creek. The city of Pipestone borders the south side of Pipestone National Monument.

Natural resource issues at Pipestone include the degradation of water quality from the development of adjacent lands outside the Monument and the loss of habitat from stream alteration and invasion of exotic vegetation. Water quality is also threatened by herbicide and pesticide runoff from agricultural lands and periodic discharge of toxicants and accidental spillage of contaminants from local industry. Although a moderate level of baseline research has been conducted in recent years, there is still a lack of basic data necessary to fully understand park resources and related threats.

2.3. Wilson's Creek National Battlefield

Wilson's Creek National Battlefield (WICR) is located 10 miles south of the city of Springfield, Missouri, on the boundary between Greene and Christian Counties in the southwestern corner of the state (Figure 2-4). The park encompasses 1750 acres, which includes approximately 75% of the historic battlegrounds. The park was established by an Act of Congress on April 22, 1960 to preserve and commemorate the Battle of Wilson's Creek. The Battlefield is significant as the site of the first major battle west of the Mississippi River. It is also significant as the site of the death of General Nathaniel Lyon, the first Union General killed in the Civil War. Lyon's death focused national attention on the potential loss of Missouri to the Confederacy. Finally, WICR retains unusually high integrity relative to other Civil War battlefields. The Battlefield lies within a karst area along Wilson's Creek approximately 2 miles upstream from its confluence with the James River and is within the upper portion of the 1,460 square mile James River Watershed. The watershed terminates at Table Rock Lake near Branson, Missouri, and is an economically important resource to the region. The park is downstream from the city of Springfield, Missouri (population 140,494) which discharges 42.5 million gallons of treated sewage effluent each day. During low flow periods an estimated 80% of the water flowing through Wilson's Creek National Battlefield is treated sewage effluent.

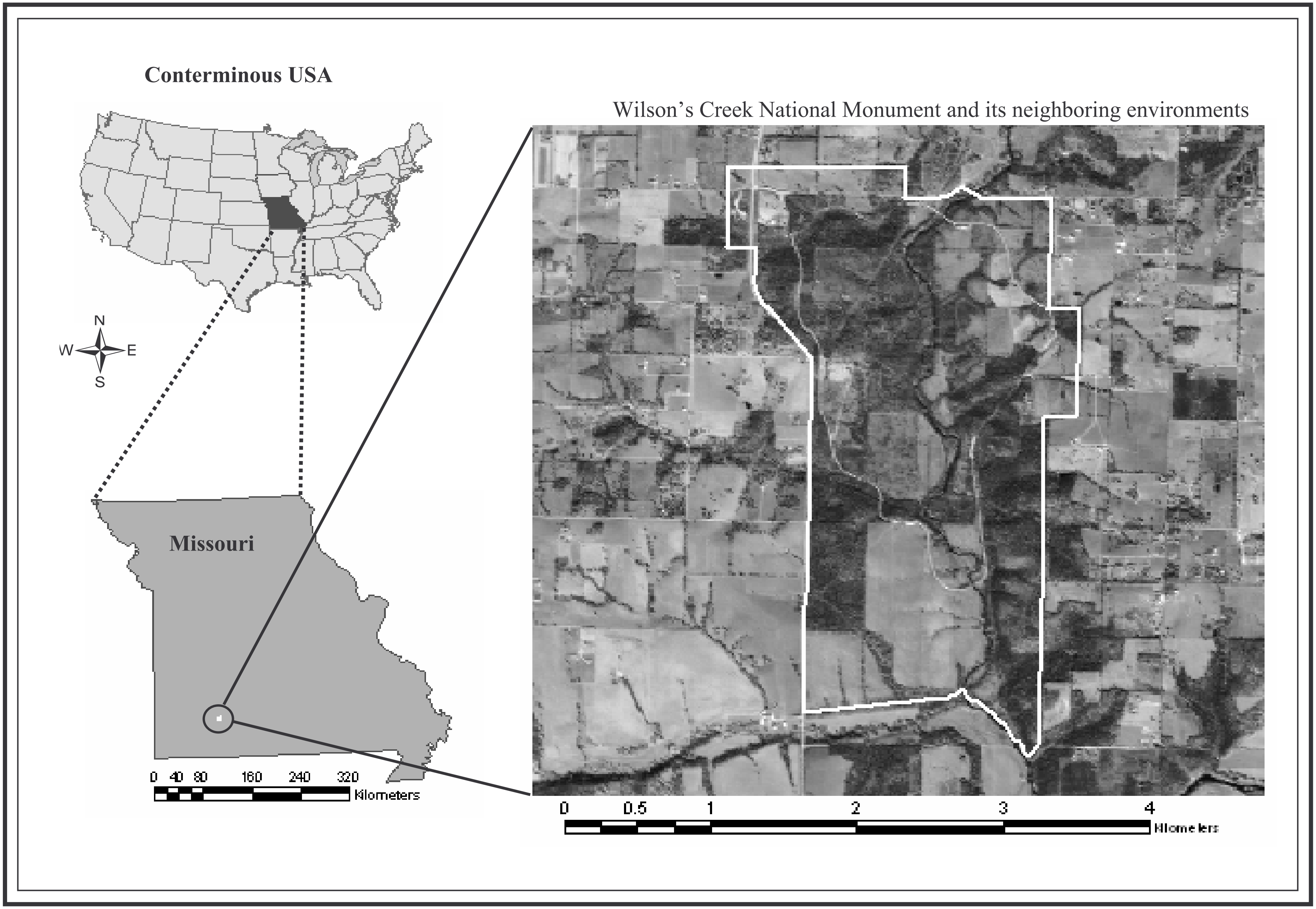


Figure 2-4: Location of Wilson's Creek National Battlefield, Missouri in the conterminous United States. The IKONOS image dated 19 November 2000 shows the entire study area with the park boundary delineated.

Vegetation and water quality are the natural resources most studied at the Battlefield. These resources have typically been the most visible to the public and are key to the visitor's understanding of the Battle and enjoyment of the facilities. The most studied plant within the park is the Missouri bladderpod, a federally endangered plant species. A population of federally endangered Indiana bats was located within the park. There are also approximately 1,100 acres of disturbed land which park staffs are trying to restore to oak savanna or historic fields that were present during the Battle. In addition, approximately 500 acres of the park are infested with exotic plant species. Water resources within the park are being adversely affected by pollution from external sources. Aquatic insects are monitored annually providing an indication of overall stream quality. Wilson's Creek is in fair condition at the present time. The park also has an active prescribed fire program to mimic the natural fire regime that created much of the savanna landscape that was present at the time of the Battle. Approximately 300 acres of vegetation are burned each year under the direction of well trained fire management personnel. There are five caves located within the park totaling approximately 60 feet of undeveloped cave passages. Two caves have been mapped and initial surveys have been made. All caves are closed to the public until a complete inventory of resources has been completed and staff can make an informed decision about their future management. Finally, development in the surrounding areas of Springfield, Republic, and Battlefield, have dwindled available wildlife habitat thus making the park a "haven" for various wildlife. The primary issue affecting the park is the drastic population growth of the surrounding region and its affect on the management of the park. Local governments must expand their infrastructure to accommodate increases in population. The result is an increase in development projects that have potential to affect park resources. Recent examples include; a proposed sewage treatment plant on the western boundary of the park, a proposed highway bypass near the park, a proposed residential development adjacent to the park, and a proposed Greenways trail from Springfield.

3. MATERIALS AND METHODS

3.1. Data Sources and Pre-processing

Aerial photography for the 1940s and 1960s was obtained from the United States Department of Agriculture's - Agriculture Stabilization and Conservation Service (USDA-ASCS). 1:20,000 scale black-and-white aerial photographs archived by USDA-ASCS Aerial Photography Field Offices served as the historical data sources were also acquired. Data for the 1990s included Digital Orthophotograph Quarter Quadrangles (DOQQs) obtained from the United States Geologic Survey (USGS). Since the mid-1990s the USGS has produced black-and-white (and occasionally color) DOQQs that meet National Map Accuracy Standards (NMAS) at a scale of 1:12,000. Photographic and terrain distortions have been removed, and the resulting images are georeferenced to a known coordinate system. Table 3-1 lists the time period of all the datasets available for the three national parks.

Table 3-1: Data acquisition dates for the three National parks

Parks	Aerial Photographs	Aerial Photographs	DOQQs	IKONOS Image
EFMO	September, 1940	October, 1961 - August, 1964	May, 1994 - August, 1997	October, 2001
PIPE	1938	1968	July, 1991 - November, 1997	April, 2001
WICR	September, 1940	October, 1961 - August, 1964	March, 1996 - June, 2000	November, 2000

To ensure a standardized digital format for all aerial photography (1940s and 1960s) used in this research, the University of Wisconsin-Environmental Remote Sensing Center (ERSC) was contracted to create digitally mosaicked orthophotographs from the historic aerial photos. The process followed USGS standards whereby a digital orthophoto was created by scanning the aerial photograph transparencies (diapositive) with an image scanner. Each scanned photograph was rectified to an orthographic projection by processing each image pixel through photogrammetric space resection equations (Fuhr *et. al*., 1999; Habib, 2002). The process required, as input, ground control points (GCPs) acquired from ground surveys or developed in aero-triangulation, conjugate photo-coordinates of ground control, camera orientation parameters, and a digital elevation model (DEM; USGS, 1996). The rectified digital images were contrast stretched, mosaicked, and had a horizontal positional accuracy of <±5 meters. The 1990s DOQQs were used as baseline data and the orthophotos of the 1940s and 1960s were registered to them. Careful geometric fidelity (± 1 pixel) was maintained in the multi-temporal registration process to avoid "dubious" changes being recorded.

To aid in the interpretation process, high-resolution, pan-sharpened (1 x 1 m) IKONOS satellite images, were used (Table 3-1). The pan-sharpened image contained color and tonal information that was considerably superior to the 1990s black-and-white DOQQs, and aided the interpretation process in cases where there was confusion between land cover categories (e.g., maple-cottonwood versus deciduous forests).

3.2. Image Interpretation

A vegetation classification scheme based on National Vegetation Classification Scheme (NVCS) "Formation" level was used to classify the land use. Anderson *et al.* (1998) and Grossman *et al.* (1998) have expanded the NVCS to "Alliance" and "Association" levels. Classification categories were derived from the NVCS and tailored using local knowledge to eliminate or collapse categories. Currently, the NVCS does not address built features (e.g., roads, urban areas) satisfactorily, so descriptions from Anderson *et al.* (1976) were used for these categories. Because of the difficulty in interpreting certain key objectives (exotic pasture, native pasture, prairie) considerable ancillary input was provided by NPS personnel and incorporated into the classification scheme. A total of twenty-five, fifteen, and nineteen land cover categories were identified at EFMO, PIPE, and WICR respectively (see Tables 3-2, 3-3, and 3-4).

On-screen digitizing with a minimum mapping unit of 1-ha was used to delineate the land use/land cover, and because image interpretation is a highly subjective discipline, it often requires the analyst to be familiar with local geography, land use history, classification scheme, and end user needs. Often several visits to a study area may be required to accomplish this. Unfortunately, the funding resources were restricted and such *in situ* visits were not performed. The development of an accurate classification, therefore, depended on the substantial and valuable, and vital feedback of the LTEM personnel and local residents.

The image interpretation was performed backwards in time – i.e., the 1990s DOQs were interpreted first with the aid of the pan-sharpened IKONOS data and LTEM staff input. An elimination process was followed by first classifying the "obvious" features

Table 3-2: Classification scheme and respective descriptors of the land cover categories used for the Effigy Mounds National Monument

Land Cover Class and Code	Description
UPLAND FORESTS/WOODLANDS (>25% TREES)	
Forested Hillside Prairie (FHP)	South- to southwest-facing slopes that were originally open oak woods, but now are forested. Map to 0.10 ha.
Silver Maple-Cottonwood Forest (FMC)	Regularly flooded floodplain along the Mississippi and Yellow Rivers. Silver maple dominates. Cottonwood, elm, and ash may be present
Nursery (FMP)	Commercial nursery operation including mixed cultivated trees and shrubs
Savanna/Woodlands (FSW)	>25% <60% Tree canopy with grass and forbe ground cover
Coniferous Forest (FED)	>60% Tree canopy
Deciduous Forest (FWO)	Deciduous trees. Canopy cover is> 60% Includes White Oak, Red Oak, Shagbark Hickory, Sugar Maple, American Elm, Basswood
SHRUBLANDS (>25% Shrubs)	
Upland Shrublands	
Upland Scrub (SUS)	Upland areas of recent clear cuts, edges of fields. One or more of the following species may be present; sumac, dogwood, black locust
Bottomland/Floodplain Forests/Woodlands/Shrublands	
Bottomland Woodland (FBW)	Bottomland tree stands with areas >25% and <60% canopy cover
Bottomland Forest (FRH)	Bottomland tree stands with areas >60% canopy cover
Bottomland Shrub (SWL)	Occur along the Yellow river and Mississippi river. This type is an early successional stage that occurs on recently flooded riparian areas
HERBACEOUS (>25% Canopy Cover)	
Upland Herbaceous	
Native Prairie Plantings (HRP)	Restored prairie and other private and commercial native prairie plantings in and around the park
Pasture (HPG)	Fields used for grazing and haying
Croplands (HCF)	Annual crops such as corn and soybeans
Bottomland/Flood Plain Herbaceous	
Bottomland Meadow (HBM)	Meadows containing a mixture of native and exotic herbaceous species
Bottomland Cropland (HBC)	Bottomland fields currently in production
Bottomland Herbaceous Old Field (HBF)	Bordering streams or other bottomlands; typically with goldenrods and other tall, weedy, and moist-loving herbaceous species
Meadows (HRC)	Wet meadow composed of rice cut-grass and reed canary grass within floodplains and bottomlands
Marsh (HRB)	Shallow water communities in Mississippi and Yellow River floodplains
OPEN WATER (non-vegetated)	
Farm Ponds (OFP)	Farm ponds and stock dams for agricultural use
Marsh Ponds (OMP)	Ponds contained in wetland areas
Rivers & Streams (ORS)	Rivers and Streams of mappable width
LAND USE	
Residential (LRS)	Buildings and land for residential use
Commercial (LCM)	Buildings and land for commercial use (e.g. visitor center)
Farmsteads and Agriculture Buildings (LFB)	Farmsteads, buildings, and adjacent lands for agricultural use
Roads and Railroads (LRR)	Roads and Railroads and their rights-of-ways

Table 3-3: Classification scheme and respective descriptors of the land cover categories used for the Pipestone National Monument

Land Cover Class and Code	Description
FORESTS/WOODLANDS(> %25 trees)	
Upland Forests/Woodlands	
Deciduous Forest (FWO)	Native, deciduous trees; less than 60% canopy cover
HERBACEOUS (>25% Canopy Cover)	
Upland Herbaceous	
Croplands (HCF)	Annual crops such as corn and soybeans
Degraded Prairie/Pasture (HDP)	Degraded native prairie that includes areas of outcropping Sioux quartzite; some used for grazing
Tallgrass Prairie	Mesic prairies with big bluestem/Indian grass and a variety of forbs
Native Prairie Plantings (HNP)	
Other Croplands (HOC)	Buffer grass (filter strips) and drainage areas greater than 10m within croplands; primarily smooth brome and reed canary grass
Pasture (HPG)	Fields used for grazing and haying
Sioux Quartzite Prairie (HQP)	Native prairie characterized by thin soils, outcropping Sioux quartzite and ephemeral pools
OPEN WATER (non-vegetated)	
Farm Ponds (OFP)	Farm ponds and stock dams for agricultural use
Rivers & Streams (ORS)	Rivers and Streams of mappable width
LAND USE	
Commercial (LCM)	Buildings and land for commercial use (e.g. visitor center)
Farmsteads and Agriculture Buildings (LFB)	Farmsteads, buildings, and adjacent lands for agricultural use.
Urban (LUR)	
Roads and Railroads (LRR)	Roads and Railroads and their rights-of-ways
Residential (LRS)	Buildings and land for residential use

Table 3-4: Classification scheme and respective descriptors of the land cover categories used for the Wilson's Creek National Monument

Land Cover Class and Code	Description
FORESTS/WOODLANDS(> %25 trees)	
Upland Forests/Woodlands	
Oak / Hickory Forest Complex (FHC)	Similar to Oak / Hickory Forest that include pockets of glades
Oak-Hickory Woodland (FHW)	Similar to Oak / Hickory Forest, primarily deciduous canopy cover 25-60%
Oak / Hickory Forest (FOH)	Canopy cover is> 60%, trees mostly deciduous common species include white, black and post oaks, mockernut and bitternut hickories
Nursery (FMP)	Tree species that are cultivated
Upland Woodland Complex (FUW)	>25% <60% Tree canopy. Composition similar to Oak / Hickory Forest with areas of glade included
SHRUBLANDS (>25% Shrubs)	
Upland Shrublands	
Upland Scrub (SUS)	Upland areas of recent clear cuts, edges of fields. One or more of the following species may be present; cedars, sumac, honey locust
Bottomland/Floodplain Forests/Woodlands/Shrublands	
Bottomland Woodland (FBW)	Bottomland tree stands with areas >25% and <60% canopy cover, frequent species include oaks, slippery elm and sycamore
Riparian Forest (FRH)	Bottomland tree stands with areas >60% canopy cover
HERBACEOUS (>25% Canopy Cover)	
Upland Herbaceous	
Croplands (HCF)	Annual crops such as corn and soybeans
Pasture (HPG)	Fields used for grazing and haying
Pasture with Trees (HTP)	Canopy cover < 25%. Areas of exotic, cool-season grasses interspersed with trees
Restored Savanna/Prairie (HSP)	Resoration areas within the park, some areas have few mature trees due to recent restoration
OPEN WATER (non-vegetated)	
Farm Ponds (OFP)	Farm ponds and stock dams for agricultural use
Rivers & Streams (ORS)	Rivers and Streams of mappable width
LAND USE	
Commercial (LCM)	Buildings and land for commercial use (e.g. visitor center)
Farmsteads and Agriculture Buildings (LFB)	Farmsteads, buildings, and adjacent lands for agricultural use
Industrial (LRI)	Power Generation and Municipal Water Treatment Facilities
Roads and Railroads (LRR)	Roads and Railroads and their rights-of-ways
Residential (LRS)	Buildings and land for residential use

of the landscape (e.g., roads, railroads, farmsteads/agricultural buildings, urban areas and rivers). Then the process focused on delineating croplands, pastures and forest patches with more than 60% canopy cover. When attempting to differentiate between pasture and cropland, some useful information included visual texture of vegetation and land, feature shape, evidence of slope, presence of row crops or tillage marks, and erosion patterns that were evident in plots being used for continuous livestock pasturing. The spatial relationship of a field to the road network, sorting pens, holding pens, and buildings were additional indicators of its use. Associative information pertaining to the shape of pastures and their location relative to roads, farmsteads, woodlands, and waterways was useful for differentiating between row crops and pasture lands.

Once the agricultural matrix, road network (from *Topologically Integrated Geographic Encoding and Referencing* (TIGER) files) and urban areas were delineated, certain small tracts of prairie, woodlots, and other land uses remained to be classified. To facilitate the interpretation of key land use categories such as grazed prairies, prairie hayfields and grazed or degraded woodlands, areas that appeared to be natural vegetation (e.g., prairie, savanna) were labeled "Potential Natural Vegetation", and NPS personnel provided the feedback and clarifications to classify these areas.

Upon completion of each time period, draft maps were produced for dissemination to LTEM staff, park staff and local experts to help determine map accuracy. Formal accuracy assessments were not performed because of the high costs involved with *in situ* data acquisition. The final land use/land cover classification maps for the three time periods were derived and utilized in the post classification change detection algorithm.

3.3. Change Detection

Biophysical materials and anthropogenic features are dynamic and can potentially change rapidly over short periods of time. To fully understand the physical and human processes at work, it is important that such changes be detected and quantified accurately (Jensen and Narumalani, 1992). Remote sensing offers an important means of detecting and analyzing temporal changes, and since the early 1970s, satellite data have been commonly used for short-term (decade or less) change detection studies (Jensen *et al.*, 1993). Ecologists increasingly recognize that a full understanding of ecosystems should be based on the analysis of their functioning over long time scales (Oldfield *et al.*, 2000). However, the use of remote sensing for long-term change studies provides considerable challenges because of the lack of easy availability, and the geometric and thematic fidelity of the data. For example, Axelsson *et al.* (2002) relied on ancillary data sources such as historical records to study changes in five mixed deciduous forests between 1866 and 1999. Despite these shortcomings, the long-term monitoring of landscape spatial pattern, in addition to biophysical variables, can lead to the detection of a greater range of processes of landscape modification (Lambin and Strahler, 1994). When performing change detection it is important to consider various sensor system and environmental parameters. Ideally, sensor system parameters such as spatial, temporal (e.g., anniversary dates), spectral, and radiometric resolutions should be held constant when feasible. In addition, variations in environmental characteristics such as atmospheric and soil-moisture conditions, and vegetation phenology should be minimal. However, few change detection studies could meet such stringent criteria even under controlled experiments. Consequently, it is necessary to adapt the available data in order to extract the best possible information from the given resources. In this study, because the land cover was manually interpreted most of the sensor and environmental issues of change detection would not have any significant ramifications in modifying the interpreted cover type.

The interpretation of changes across the temporal dimension was addressed by observing changes in the visual details of a field or tree plot between two temporal data sets and recording the changes. For example, the LU/LC interpretation for the time periods preceding the 1990s showed that a number of small ponds impounded by earthen dams were decreasing. These changes were verified by overlaying the 1990s classification on the 1960s photography, querying the database for the farm ponds class, and then verifying the land cover type in the underlying 1960s (or 1940s) data.

After each date of aerial photography was interpreted, the post-classification change detection algorithm was used to determine changes between three time periods including 1940s-1960s, 1960s-1990s, and 1940s-1990s. Post-classification change detection is the most commonly used method of change detection (Jensen *et al.*, 1993). When image-map products for two or more dates are produced, they can be compared on a pixel-by-pixel basis to pinpoint any changes that may have occurred between the time periods. The change that was extracted for the three time periods was represented in a series of change detection matrices that depicted (a) “from-to” land cover classes, (b) the total area of change between the classes, and (c) specific color representation of change for select classes. Selected classes were draped on the aerial photographs to highlight the spatial locations of where these changes had occurred. While the change detection technique quantified several facets of the change (including its spatial location), it did not reveal changes in the geometry and fragmentation of the land cover classes. Therefore, a suite of landscape metrics were calculated that provided an overall perspective of the class level changes in the landscape.

3.4. Derivation of Landscape Metrics

A landscape is defined as a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout (Forman and Godron, 1986). It is typically composed of several types of landscape elements (patches) which represent regions that have the same habitat class and relatively homogenous environmental conditions. The delineation of land use/land cover and the extraction of change detection information as described in the preceding sections forms the baseline from which knowledge of landscape properties can be derived. The understanding of spatial distribution, arrangement across the landscape, contiguity, and fragmentation can be addressed through the application of landscape metrics (Herzog and Lausch, 2001).

Landscape metrics act as the quantitative link between landscape patterns and ecological or environmental processes. They are commonly used to create quantitative measures of spatial patterns found on a map or remote sensing image. When viewing a satellite image, many elements can be identified, which when combined characterize the physical aspects of the scene. Some of these elements, including variations in shape, size, texture, and patterns, have formed the basis of aerial photointerpretation. The use of landscape metrics allows the quantification of these groups of elements into measurable variables. By quantifying spatial patterns and their changes we can measure their effect on ecological processes, as well as determine the suitability of a given habitat type for a particular species (Frohn, 1997).

Many change detection investigations tend to focus on a general description of the vegetation and may present satellite data as a qualitative tool for studying specific ecosystems (e.g., Sader *et al.*, 1990; Carlson *et al*., 1999). Rainis (2003) suggests that in addition to studying the composition of land use types, their spatial distribution and arrangement also need to be considered for monitoring changes. Herzog and Lausch, (2001) proposed the use of landscape metrics that address landscape patterns and are based on analyzing the geometry and spatial arrangement of land use/land cover patches. For several decades, quantitative measurements of landscape pattern (called metrics or indicators) have been used to link ecological and environmental processes with patterns found in the landscape (Krummel *et al.*, 1987; O'Neill *et al.*, 1988; Bunnell, 1997; Prabhu *et al.*, 2001). Resource managers require spatial and temporal information in order to make decisions that will have lasting ramifications on the landscape. Consequently, mapping the landscape through time, incorporating spatial relationships, and quantifying its structure are critical components of any study that analyzes a changing landscape.

Changes in a landscape are a result of complex interactions between physical, biological, economic, political, and social forces. Most landscapes have been influenced by human land use, and the resulting landscape mosaic is a mixture of natural and human-managed patches that vary in size, shape, and arrangement (Turner, 1989). To quantitatively assess landscape change, a suite of metrics are often computed. Metrics can be derived for one of three levels: patch level (defined for individual patches), class level (characteristics of all patches in a given class), and the landscape level (integrated over all patch types or classes over the extent of the data). Patch metrics are too disaggregated and can be more useful when analyzing single patches for specific purposes (e.g., habitat studies, reserves delineation, edge effects; Cunningham, 2000). However, when comparing a single landscape structure, over different periods of time, class metrics provide important elements describing general patterns within the landscape.

Our focus was on analyzing the temporal change of the class level metrics, which are integrated over all the patches of a given type (class). This integration may be accomplished by simple averaging, or through a weighted-averaging scheme for biasing the estimate to reflect the greater contribution of large patches to the overall index. The analysis was directed toward a few habitat classes which showed maximum change over the three time periods and included computation of four class-level metrics including class area, number of patches, mean patch size, and area weighted mean patch fractal dimension for the three time periods. While digitizing care was taken to keep the aerial photographs at a scale 1:2,000 for each time period. In addition, the cell size was kept constant at 1 meter for calculating the landscape metrics keeping in mind that any variations in the scale of digitization and cell resolution would affect our analysis of landscape pattern, especially mean patch fractal dimension. A 3 x 3 window was used so that an 8-cell patch neighbor rule could be used for determining patch membership.

Forman and Godron (1986) offer substantive discussions of the effects of patch size on energy and nutrients, and on species diversity. Size of a patch is an important characteristic of the landscape while analyzing community structure, based on the fact that larger patches generally hold a greater number of species than smaller patches (Lavers and Haines-Young, 1993). The smaller the fragmented blocks, the more the density of a population decreases and the risk of species extinction grows (Farina, 1998). Consequently, if mean patch size is analyzed in conjunction with other metrics such as the number of patches, it can be used to measure fragmentation.

Mean patch fractal dimension has been used in ecosystem change analysis to quantify the complexity of patch shapes on a landscape (Krummel *et al.*, 1987; O'Neill *et al.*, 1988; De Cola, 1989; Lam, 1990). It has been used as a measure of degree of human disturbance on the landscape. The premise is that natural boundaries such as those for vegetation have more complex shapes than those that are a result of human activity, such as agricultural fields. As human disturbance increases, the fractal dimension of the landscape decreases (Krummel *et al.*, 1987; O'Neill *et al.*, 1988; Turner and Ruscher, 1988; De Cola, 1989). Patch fractal dimension is very critical in linking the landscape pattern to ecological process.

3.5. Derivation of threat vectors representations (For Wilson's Creek only)

WICR has operated under a 1977 master plan, and since then the park and its surroundings have changed significantly (NPS, 2002). The population of the Springfield metropolitan area grew from 207,704 to 240,593 between 1980 and 1990 and increased to 281,767 by 1995. The population of Greene County (northeast) increased from 152,928 to 218,095 between 1970 and 1995, while that of Christian County grew from 15,124 to 38,433 in the same period (NPS, 2002). The impact of the population growth and encroaching suburban development around the park would undoubtedly be harmful for the park habitat. Regional planners predict that approximately 20,000 acres of undeveloped land in the Springfield area would be converted to housing and 65,000 people are expected to move into the area between 2000 and 2020. As the regional population grows, residential development on former agriculture fields would become visually prominent from areas within the park. This development undoubtedly would intrude upon historical context of the park and have an adverse effect on the scenic as well as natural resources within the park.

Representations of threat vectors based on the growing residential pressure towards the park boundary were modeled for a period of 60 years. The study area was divided into 1 mile buffers from the park boundary, for a distance of 3 miles, and the buffer was segmented into 8 vectors drawn at 45^{o} angles to represent compass directions. Residential growth pressure for each segment was calculated by the following formula, thus producing normalized values:

$$\text{Residential pressure (at each segment) (\%)} = \frac{\text{Total residential areas in a segment (hectare)}}{\text{Total area of that segment (hectare)}} \times 100 \quad \ldots (1)$$

4. RESULTS

A land cover classification scheme comprised of various land cover classes and their definition was determined at all the three parks. The final land use/land cover classification maps for the three time periods (40s, 60s, & 90s) based on the classification scheme were derived and utilized in the post classification change detection algorithm as well as in landscape metrics analysis. Change detection products can be used to illustrate and explain the changes that occurred over the given time period, however, it should be emphasized that these are derived from single time-frame aerial photography – i.e., they are “snap-shots” for given time-periods. Change is a dynamic phenomenon and a continual detection and quantification of change is a virtual impossibility. However, examination of static map products derived at given time intervals provide valuable insights to the user on specific changes, trends, and a historical perspective.

Change detection products provided in this report are of two kinds including (a) maps, and (b) matrices. The focus of this project and subsequently of this section on change detection is on the ramifications of human (or human-induced activities) on the “natural” vegetation cover within and around a specified area of the three national parks/monuments. Map products provide the user with a visual assessment of “where” change has occurred in these parks. The maps provided in this report focus on specific changes (e.g., a forested area having been converted to pasture) that pertain to impacts on “natural” vegetation. Change detection *matrices* highlight specific (natural vegetation related) categories of “from-to” change (i.e., “what” has changed), and the specific area lost or gained by the given classes.

While the conventional change detection methods described changes in class area and the spatial location of such changes, landscape metrics will provide an insight to the impact of such change. O'Neill *et al.* (1996) used three-dimensional pattern space to analyze the landscape in three regions in the southeastern U.S. This method is powerful because it can also be used to assess the direction and magnitude of change through time. Metrics that describe landscape diversity and fragmentation include class area, number of patches, and mean patch size, while fractal dimension evaluates patch complexity (i.e., shape of a patch changing from a simple geometric shape to a highly convoluted, extremely complex type) and human influence on a given patch. In this research, the three-dimensional pattern space was defined by number of patches, mean patch size, and area weighted mean patch fractal dimension as the x, y and z axes respectively to visualize the fragmentation and human influence for selected land cover categories.

4.1. <u>EFMO North Unit and South Unit (Sny Magill)</u>

4.1.1. Classification and Image Interpretation

<u>North and South Unit</u>

Twenty five different land cover categories were identified at both north and south units of EFMO. Final land cover classification maps showed that major portions of the parks are covered by deciduous forest (Figures 4-1 and 4-2). This dominant land cover occupied greater than 40% of the total land at EFMO north unit and greater than 30% at EFMO south unit for all 60 years from 1940s to 2000. Croplands and pastures were found to be the next dominant land covers. In the north unit several land cover

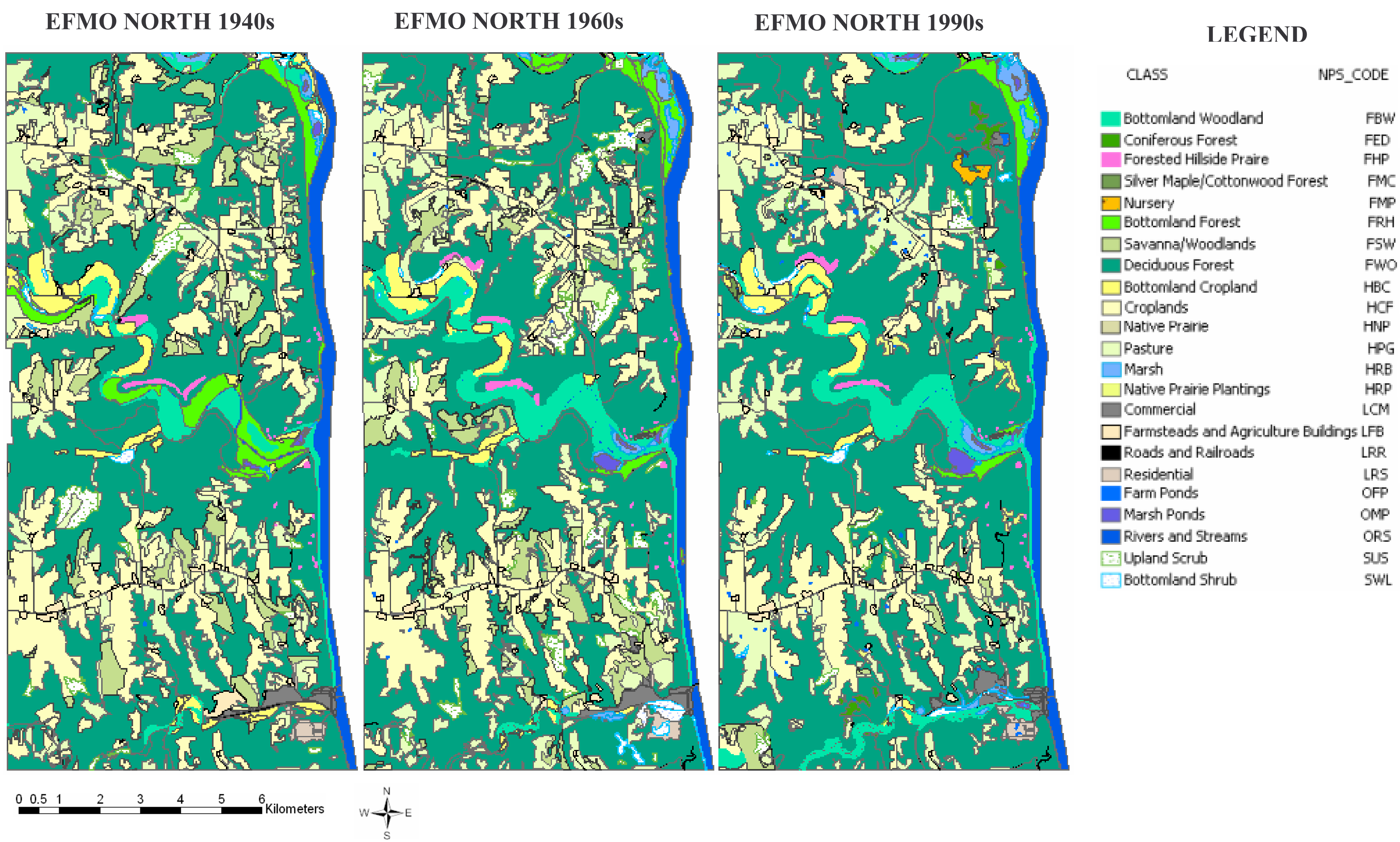


Figure 4-1: Land use/land cover classification maps of EFMO north unit for the 1940s, 1960s, and 1990s derived from the image interpretation process

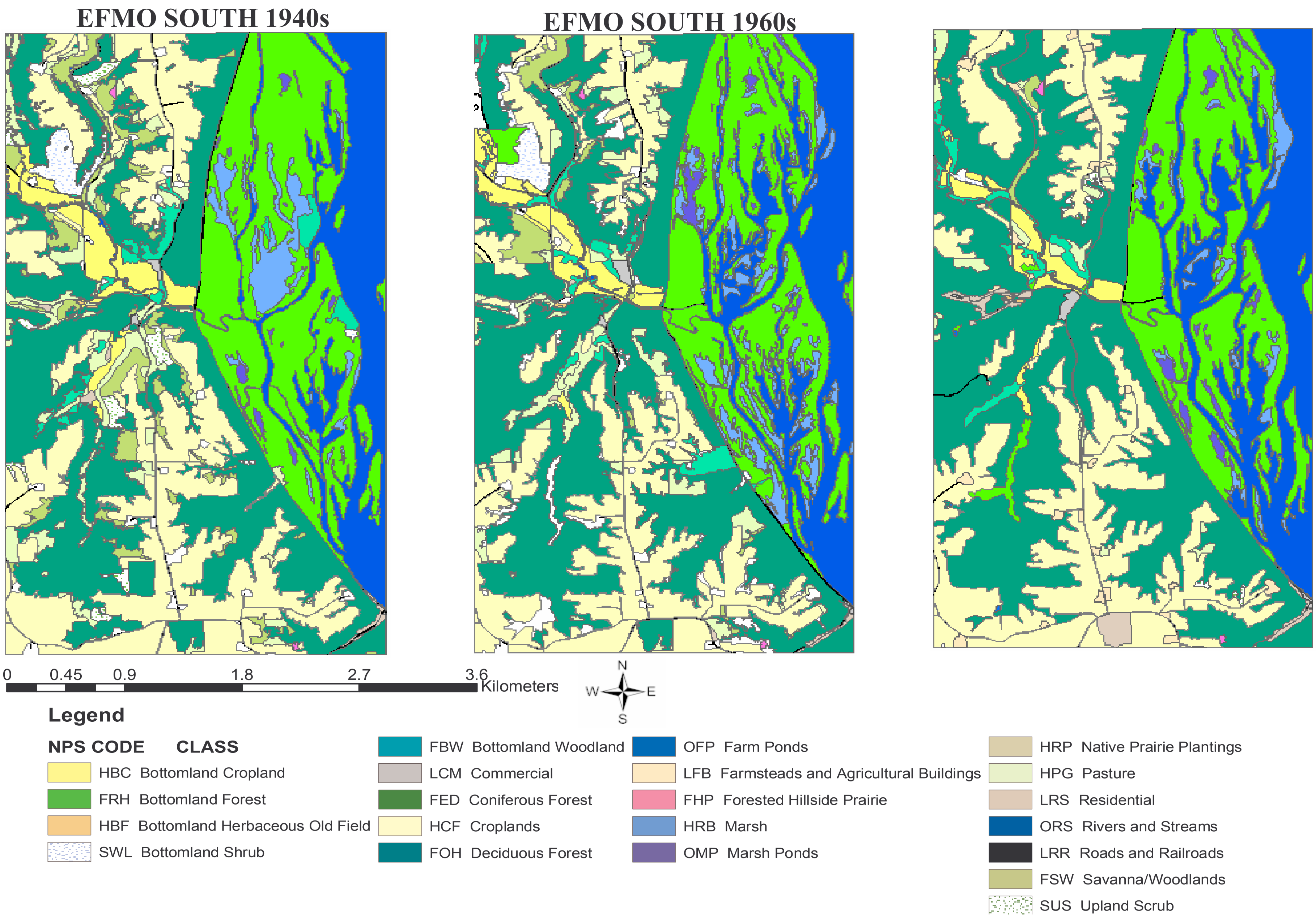


Figure 4-2: Land use/land cover classification maps of EFMO south unit for the 1940s, 1960s, and 1990s derived from the Image interpretation process

classes including deciduous forest, savanna/woodlands, croplands, bottomland woodland, bottomland forest, and pasture showed very high temporal change in their class area compared to other classes (Figure 4-3). In the south unit several land cover classes including deciduous forest, bottomland woodlands, bottomland croplands, croplands, bottomland forest, upland scrub and pasture showed very high temporal change (Figure 4-4) in their class area compared to other classes.

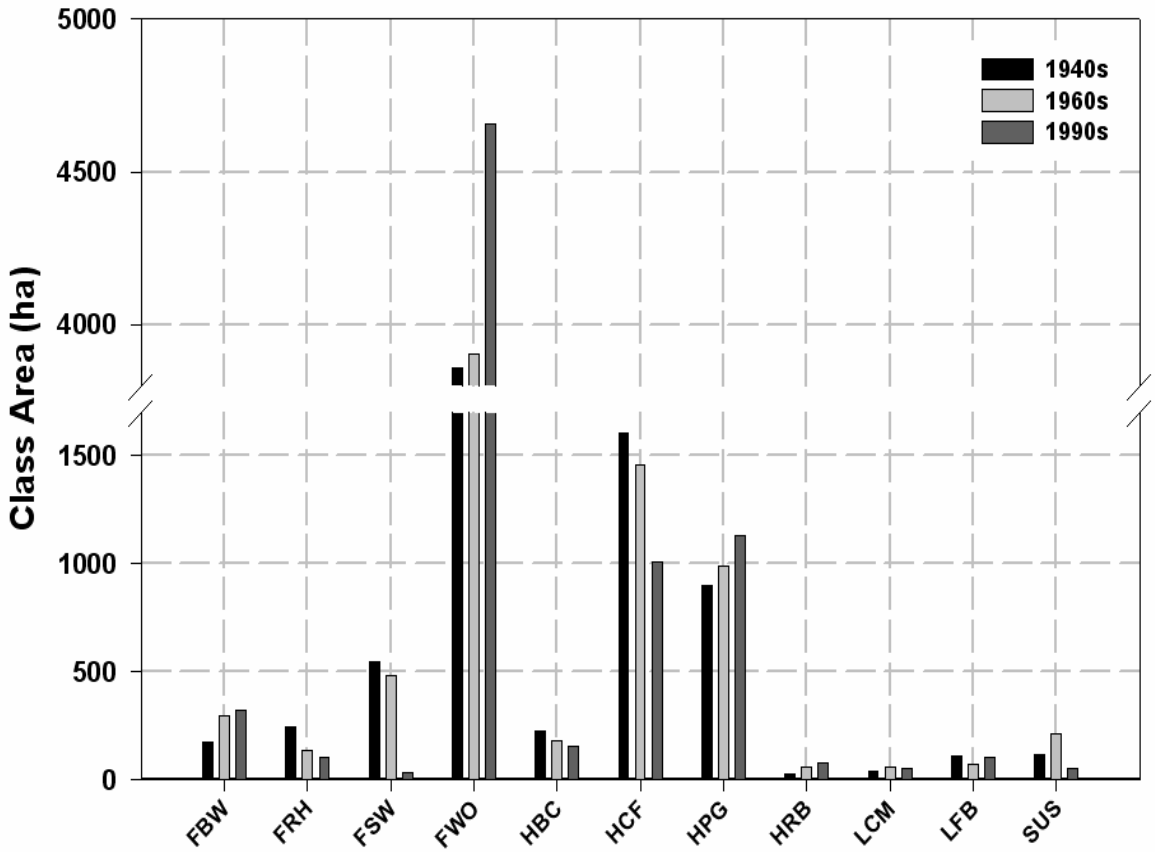


Figure 4-3: Total area of different land cover classes at EFMO north unit

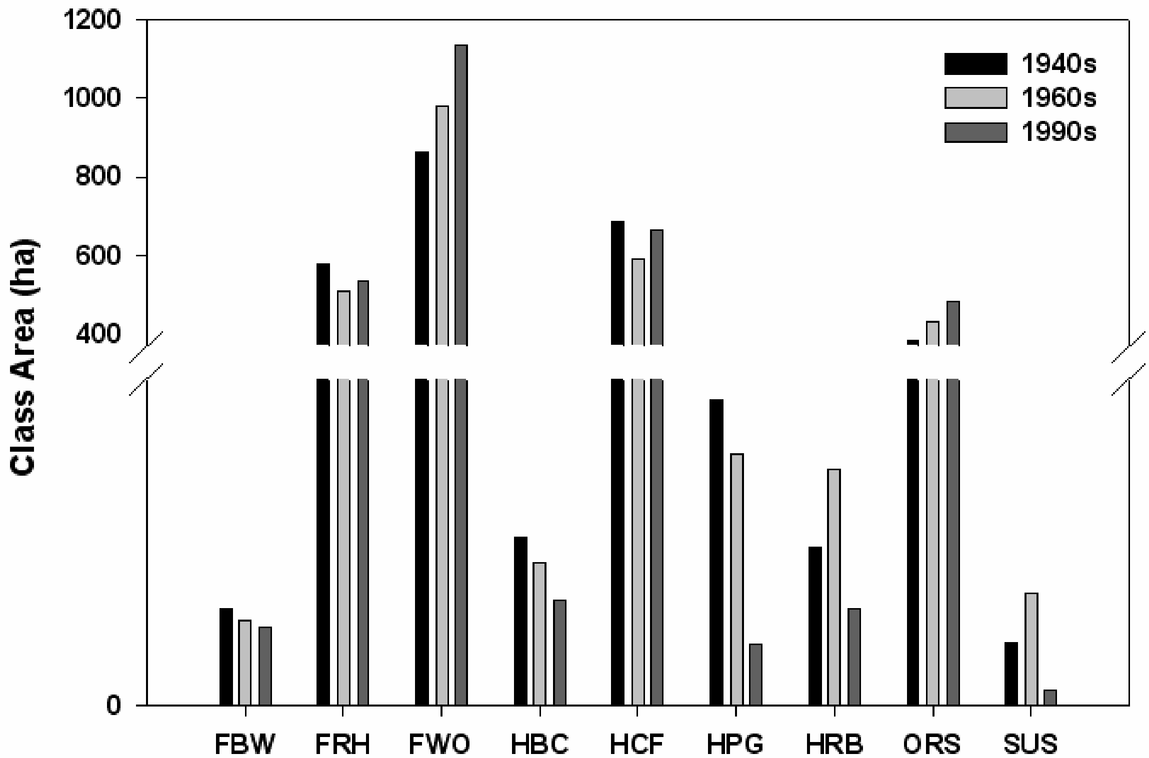


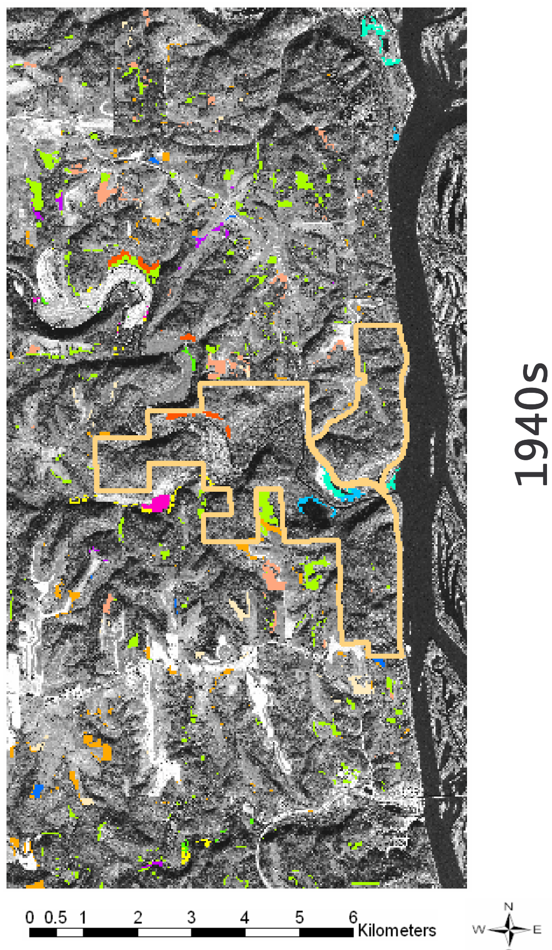
Figure 4-4: Total area of different land cover classes at EFMO south unit

4.1.2. Change Detection

North Unit

Change detection results for EFMO north unit for 1940s – 1960s show major changes, especially with reference to natural vegetation that included (a) net gain in bottomland woodland and marsh land, (b) increases in the number of farm ponds, and (c) a general gain of bottomland shrub resulting from a reduction in canopy cover likely the result of timber harvest (Figure 4-5). Between the 1960s-1990s, large areas (387 ha) of savanna woodlands experienced canopy closure and were, therefore, classified as deciduous forest in the later date (Figure 4-6). Some losses in the area of natural

Location of changes for highlighted classes in the table



Effigy Mounds Change Detection: 1940s-1960s North (hectares)

1960s (columns) / 1940s (rows)

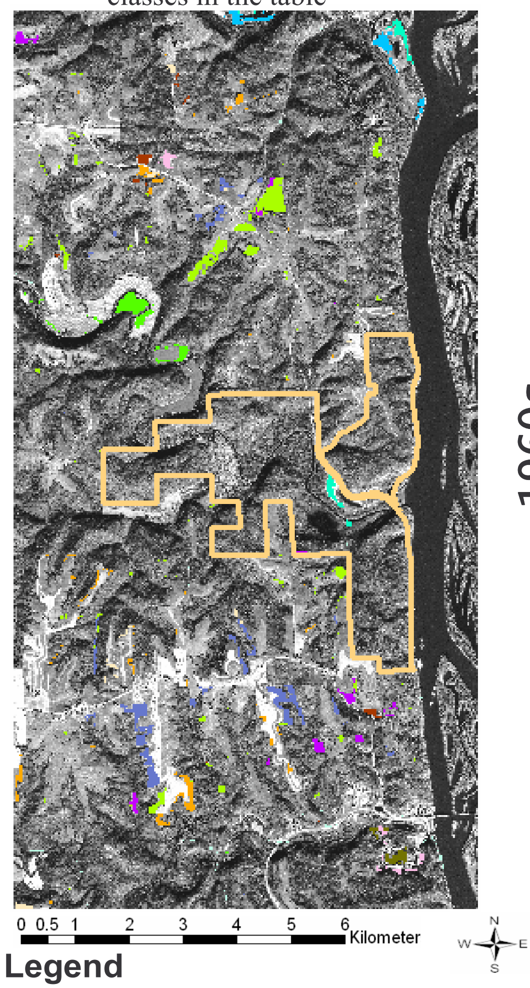
Class	FMC	FMP	FSW	FWO	FBW	FRH	FHP	HRP	HCF	HBC	HRB	HPG	LRS	LCM	LFB	LRR	OFP	OMP	ORS	SUS	SWL	FED
FMC																						
FMP																						
FSW				256	1				24			51			3					58		
FWO			234		21		15		60	11	1	136	2	1	3	6			2	69	17	
FBW				3		21				4	14					1		2	5			
FRH				19	118					1	9							9	8	2		
FHP				8	1																	
HRP																						
HCF			16	67		4				2		310		2	6	6	1			16	1	
HBC				9	21	5					9	14		3	4	2			2		10	
HRB					1	10			1													
HPG			71	133		2			166	2				6	3	3				65	4	
LRS				4										1							6	
LCM																1						
LFB			8	6	3				20		1	16		1		2						
LRR				3					3			2	2	8							1	
OFP																						
OMP											6											
ORS				2	13	2				2											2	
SUS			2	96					6			9				1						
SWL					8	3				8	1											
FED																						

Legend

- Park Boundary
- Savanna/Woodlands to Croplands
- Savanna/Woodlands to Pasture
- Deciduous Forest to Forested Hillside prairie
- Deciduous Forest to Croplands
- Deciduous Forest to Bottomland Croplands
- Deciduous Forest to Pasture
- Bottomland Woodland to Bottomland Cropland
- Bottomland Woodland to Marsh
- Bottomland Forest to Marsh
- Upland Scrub to Croplands
- Upland scrub to Pasture
- Bottomland Shrub to Bottomland Croplands

Figure 4-5: Selected land cover change for EFMO north (1940s-1960s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1990s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Legend

- Park Boundary
- Savanna/ Woodlands
- Savanna/ Woodlands to Pasture
- Deciduous Forest to Croplands
- Deciduous Forest to Pasture
- Deciduous Forest to Residential
- Deciduous Forest to Farmsteads
- Deciduous Forest to Roads and Railroads
- Deciduous Forest to Bottomland Cropland
- Deciduous Forest to Marsh
- Bottomland Forest to Marsh
- Upland Scrub to Pasture
- Bottomland Shrub to Residential

Effigy Mounds Change Detection: 1960s-1990s North (hectares)

1990s (columns) / 1960s (rows)

Class	FMC	FMP	FSW	FWO	FBW	FRH	FHP	HRP	HCF	HBC	HRB	HPG	LRS	LCM	LFB	LRR	OFP	OMP	ORS	SUS	SWL	FED
FMC																						
FMP																						
FSW		1		387	2				7			48	2	4	2	1				12		
FWO			41		30	6	2		26	4	2	61	8	3	7	5	2		1	7	4	4
FBW	4			34						20	11					1		2	8		6	
FRH					15						13		1					7	3			
FHP				5																		
HRP																						
HCF		14	1	81				6				394	4	2	17	4	1			2	3	14
HBC	1			13	14			3			2	1							2		12	1
HRB				2	4	1												7	1			
HPG		3	13	213	7	1	4	32	57					11	12	3	2			27		12
LRS					1											2						
LCM				1	2						6	4				6		2			7	
LFB				2					2			4		1		1						
LRR				5	2				2	1	1	2		1	1						1	
OFP																						
OMP																						
ORS	1			2	3	2				1											1	
SUS			4	168		2			1			17			3							11
SWL				10	12							3	6	2				2	2			
FED																						

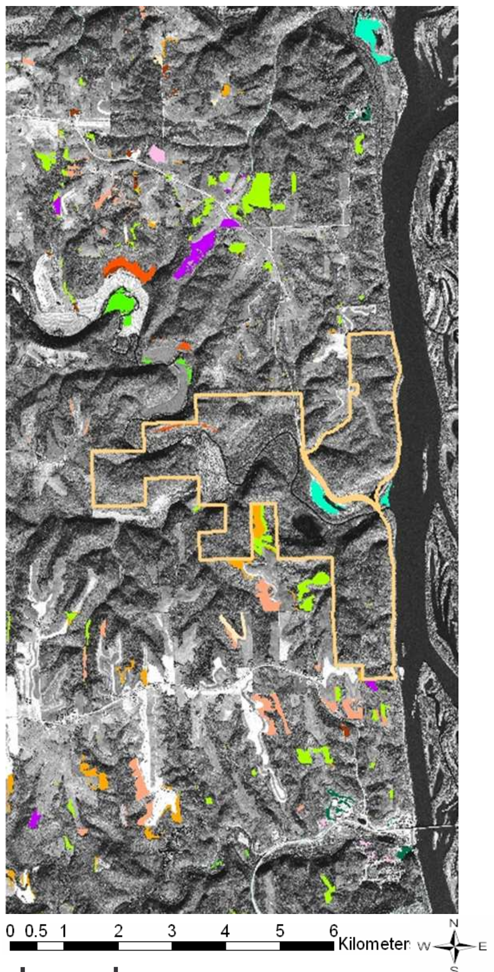
Figure 4-6: Selected land cover change for EFMO north (1960s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1960s-1990s), which quantify the amount of change in hectares.

vegetation (e.g., deciduous forest, bottomland woodland) were due to the expansion of roads, farmsteads/agricultural buildings and railroads in the area. There was a 30% decline (394 ha) in cropland mainly due to conversion into pasture, while other pasture areas were, in turn, re-colonized into deciduous forest (194 ha). Overall changes in natural vegetation between 1940s - 1990s at EFMO north unit showed divergent trends. Some areas of deciduous and bottomland woodlands experienced a decrease in canopy cover, while other areas transitioned from croplands in the 1940s to forested areas in the 1990s (Figure 4-7). A major change was the tremendous rise in the total area of farm ponds from 0.6 ha in the 1940s to nearly 162 ha in the1990s indicating changes in agricultural practices over the 60 year time frame. Bottomland forest was the most significantly impacted natural vegetation cover, losing nearly 60% of their acreage in the 60 years.

South Unit

Change detection results for EFMO south unit for the period 1940s-1960s show that major changes, especially with reference to natural vegetation include increase in canopy for savanna woodlands, which by the 1960s had become full canopy deciduous forest. Similarly, upland scrub areas also had increase in canopy, gaining from pastures that were probably invaded by more trees (Figure 4-8). Marsh areas had also increased, potentially due to water levels rising. The period 1960s-1990s saw changes because of the growth of residential areas from deciduous forest (approximately 16 hectares). As in the EFMO north, large numbers of farm ponds were also evident in the EFMO south 1990s, implying changes in cultivation measures and soil conservation.

Location of changes for highlighted classes in the table



Effigy Mounds Change Detection: 1940s-1990s North (hectares)

1990s (columns) / 1940s (rows)

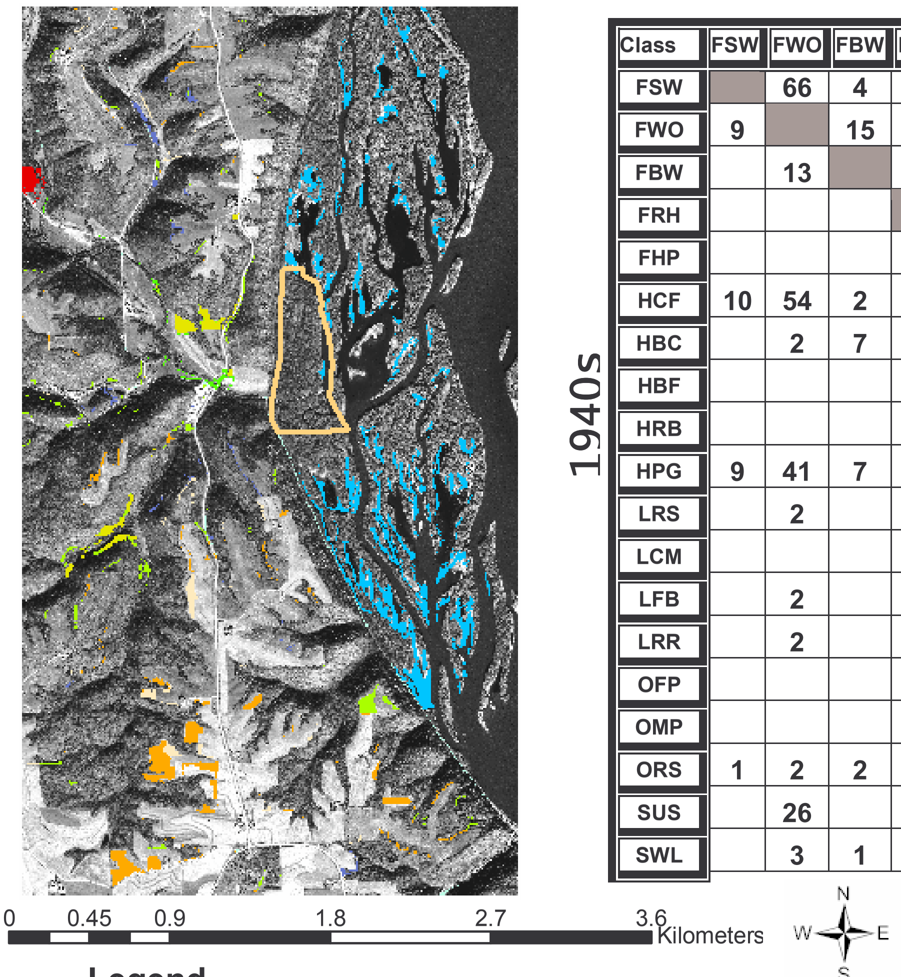
Class	FMC	FMP	FSW	FWO	FBW	FRH	FHP	HRP	HCF	HBC	HRB	HNP	HPG	LRS	LCM	LFB	LRR	OFP	OMP	ORS	SUS	SWL	FED
FMC																							
FMP																							
FSW		1		436				6	8		2	5	59			4	1				15	2	
FWO			37		36		15		45	5	2		95	7	9	8	7	2		2	4	8	4
FBW				3		7				15	23								4	6			
FRH	3			30	102					1	7			1					16	6			
FHP				7						1													
HRP																							
HCF		17	5	141	6	4		31			2	5	462	2	7	11	4	2			7	3	26
HBC				13	31	6		4			10	2	11		3	4	1		3	2		7	
HRB						2													4	1	1		
HNP																							
HPG		1	13	293	1	1		1	70					1	7	4	1	3			26		12
LRS				2											1		1	1					
LCM											6						3		2			6	
LFB				17	2				6		1		7		5		2					1	
LRR				2	5						1			1	1							1	
OFP																							
OMP											5												
ORS				2	9					2													
SUS				81	4								23	2		4							
SWL	2				5	3					1									1			
FED																							

Legend

- Savanna Woodlands to Croplands
- Savanna Woodlands to Pasture
- Deciduous Forest to Forested Hillside Praire
- Deciduous Forest to Croplands
- Deciduous Forest to Pasture
- Deciduous Forest to Residential
- Deciduous Forest to Commercial
- Deciduous Forest to Farmsteads
- Deciduous Forest to Roads and Railroads
- Bottomland Woodland to Bottomland Cropland
- Bottomland Woodland to Marsh
- Upland Scrub to Pasture

Figure 4-7: Selected land cover change for EFMO north (1940s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1990s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Legend

- Park Boundary
- Savanna/Woodlands to Croplands
- Savanna/Woodlands to Bottomland Croplands
- Savanna/Woodlands to Pasture
- Deciduous Forest to Croplands
- Deciduous Forest to Pasture
- Deciduous Forest to Roads and Railroads
- Bottomland Woodland to Bottomland Croplands
- Bottomland Woodland to Pasture
- Bottomland Forest to Marsh

Effigy Mounds Change Detection: 1940s -1960s South (hectares)

1960s (columns); 1940s (rows)

Class	FSW	FWO	FBW	FRH	FHP	HCF	HBC	HBF	HRB	HPG	LRS	LCM	LFB	LRR	OFP	OMP	ORS	SUS	SWL
FSW		66	4			6	3			5				1				10	
FWO	9		15	11		26	2			13	1		1	4			1	10	4
FBW		13		15			2		1	8				1			2		
FRH									70							6	57		
FHP																			
HCF	10	54	2				2			55	1		2	8				15	6
HBC		2	7			5				8		2	1	1			2		2
HBF																			
HRB				9												8	40		
HPG	9	41	7	2		15	2							2				20	
LRS		2					1			1				1					
LCM																			
LFB		2				6				1				1					
LRR		2		4		5	1			2	1								
OFP																			
OMP				3					6										
ORS	1	2	2	21			2		20							2			
SUS		26				2	1			1									
SWL		3	1	2			2							1					

Figure 4-8: Selected land cover change for EFMO south unit (1940s-1960s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1960s), which quantify the amount of change in hectares.

The loss of 394 hectares from cropland to pasture is an indication of changing agricultural practices in the area (Figure 4-9). Overall changes in natural vegetation between 1940s - 1990s at EFMO south showed interchangeable shifts whereby some areas of deciduous and bottomland woodlands thinned-out canopies, whereas others transited from croplands in the 1940s to full growth forested areas in 1990s (Figure 4-10). The main changes were the growth of residential areas, the loss of bottomland woodland (approximately 26% of the original area), and substantial loss of pasture (HPG).

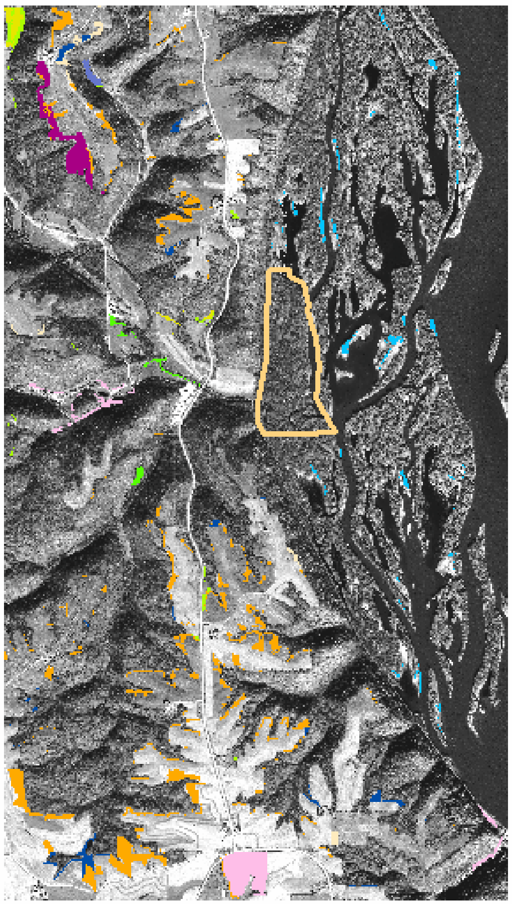
4.1.3. Landscape Metrics

North Unit

Land cover classes including deciduous forest, savanna/woodlands, croplands, bottomland woodland, bottomland forest and pasture showed high temporal change in their number of patches, patch size, and fractal dimension (Table 4-1) compared to other classes and are, therefore, examined in 3-D landscape pattern space. For example, deciduous forest experienced a net increase of 66 hectares in their mean patch size over 60 years although a much smaller percentage of clearings occurred to pave the way for agriculture, farm ponds and agricultural buildings.

The temporal shifts for this cover type indicates it has become less fragmented (number of patches are declining while their size is increasing; Figure 4-11a). However, the decline in mean patch fractal dimension indicates that the configuration of the boundaries of deciduous forests is being affected by human influences, thus regularizing the patch shapes. Depending on the land cover class adjacent to forest patches, different effects may be observed in terms of ecological processes.

Location of changes for highlighted classes in the table



0 0.45 0.9 1.8 2.7 3.6 Kilometers

N W E S

Legend

- Park Boundary
- Savanna/Woodlands to Croplands
- Savanna/Woodlands to Pasture
- Deciduous Forest to Croplands
- Deciduous Forest to Pasture
- Deciduous Forest to Residential
- Bottomland Woodland to Bottomland Cropland
- Bottomland Woodland to Pasture
- Bottomland Forest to Marsh
- Upland Scrub to Croplands
- Bottomland shurb to Croplands

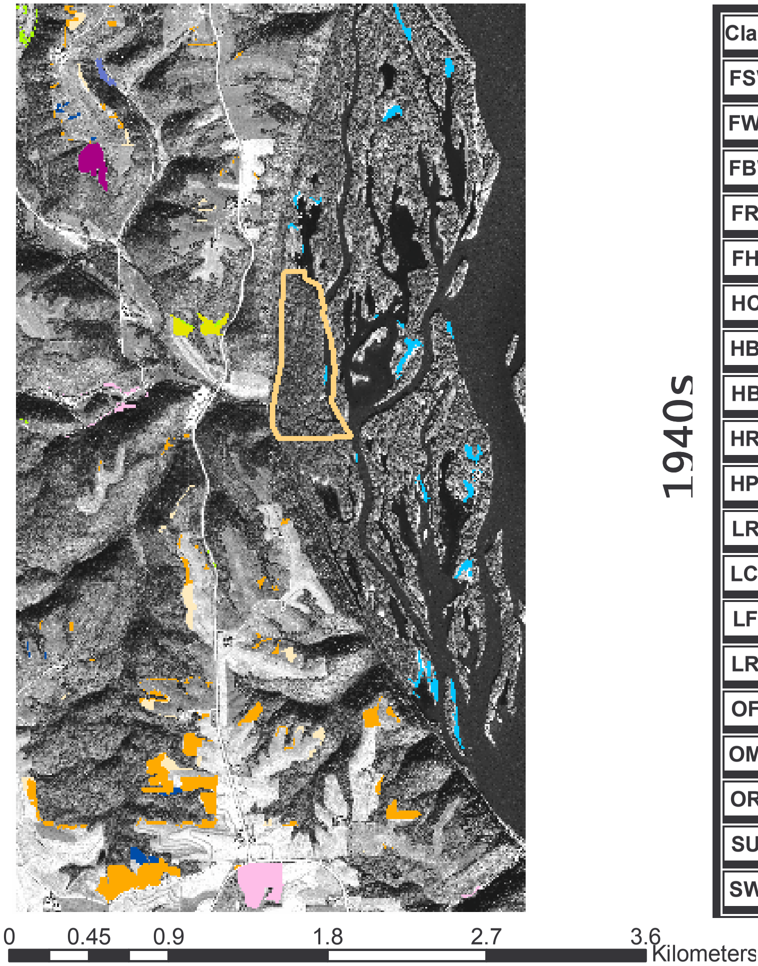
Effigy Mounds Change Detection: 1960s-1990s South (hectares)

1990s (columns) / 1960s (rows)

Class	FSW	FWO	FBW	FRH	FHP	HCF	HBC	HBF	HRB	HPG	LRS	LCM	LFB	LRR	OFP	OMP	ORS	SUS	SWL
FSW		47				3				2									
FWO	2		2	7		49	1			4	15	2	1	2			1	1	
FBW	3	23		1		1	2			3							1		
FRH		11	1						8					1		5	34		
FHP																			
HCF		29								13	2		8	4				2	
HBC		11	9	4		2								2			1		
HBF		1																	
HRB				46												14	31		
HPG		48	6	2		49	3				5	1	1	1				3	
LRS		1				1													
LCM			2							2									
LFB		2				3				1	1								1
LRR		9	1			6					1		1						
OFP																			
OMP				2													9		
ORS		1	1	14					10										
SUS		38	2	5		8	1			2									
SWL		20				10													

Figure 4-9: Selected land cover change for EFMO south unit (1960s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1960s-1990s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Effigy Mounds Change Detection: 1940s-1990s South (hectares)

1990s (columns) / 1940s (rows)

Class	FSW	FWO	FBW	FRH	FHP	HCF	HBC	HBF	HRB	HPG	LRS	LCM	LFB	LRR	OFP	OMP	ORS	SUS	SWL
FSW		102				11				1									
FWO	1		3	8		44				2	13	2	1	3				1	
FBW		17		15			2			4							3		
FRH									13							14	79		
FHP																			
HCF		83								10			5	6				4	
HBC		11	14	2		4				3	1		1	1			1		2
HBF																			
HRB				5													55		
HPG		75	7	6		16	2				7	1	2	2				2	
LRS			1				1												
LCM			1							1									
LFB		2				5				2									1
LRR		3		4		6					1		1						
OFP																			
OMP				1															
ORS	1	3	2	13			1		15							2			
SUS		28				3													
SWL		19		1		6	2												

Legend

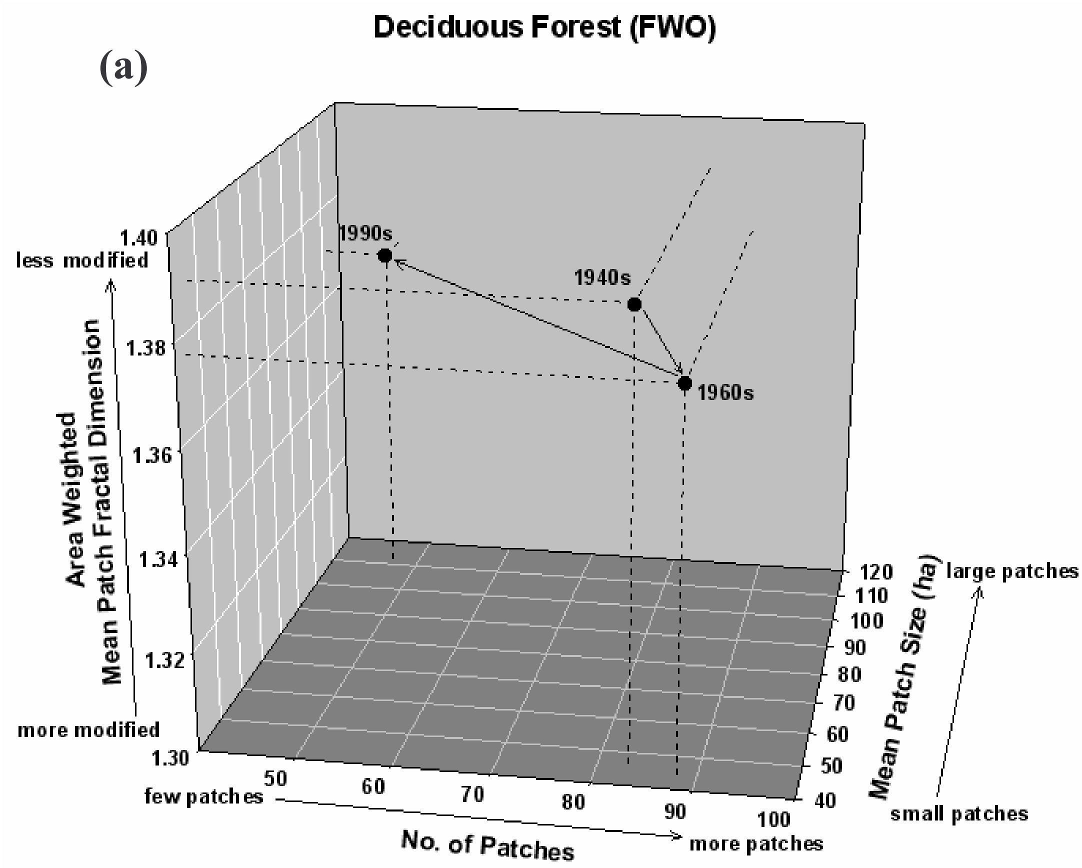
- Park Boundary
- Savanna/Woodlads to Croplands
- Savanna/Woodlands to Pasture
- Deciduous Forest to Croplands
- Deciduous Forest to Pasture
- Deciduous Forest to Residential
- Bottomland Woodland to Pasture
- Bottomland Forest to Marsh
- Upland Scrub to Croplands
- Bottomland Shrub to Croplands

Figure 4-10: Selected land cover change for EFMO south unit (1940s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1990s), which quantify the amount of change in hectares.

Table 4-1: Landscape metrics of selected land cover categories at EFMO north

Year	No. of Patches	Mean Patch Size	Area Wt. Mean Patch Fractal Dimension
Deciduous Forest			
1940s	83	46.518	1.389
1960s	88	44.369	1.376
1990s	47	112.592	1.370
Savanna/Woodlands			
1940s	64	8.573	1.141
1960s	78	6.161	1.366
1990s	14	2.283	1.123
Bottomland Forest			
1940s	15	16.167	1.208
1960s	14	9.890	1.209
1990s	9	11.104	1.197
Bottomland Woodland			
1940s	35	5.027	1.175
1960s	43	6.927	1.354
1990s	48	6.647	1.168
Croplands			
1940s	128	12.565	1.338
1960s	87	16.745	1.143
1990s	77	13.110	1.120
Pasture			
1940s	169	5.321	1.153
1960s	171	5.789	1.365
1990s	137	8.240	1.162

If forest patches border upon open vegetation, such as production areas, the patch may be more susceptible to disturbances in its structure and become more regular in shape, thus decreasing the fractal dimension. Conversely, if forest patches are adjacent to succession areas, secondary re-growth may be accelerated, which will increase the fractal dimension. By contrast, the savanna/woodlands cover type has experienced considerable decline. Fragmentation of this cover type is implied between the 1940s-1960s because of a decline in area accompanied by an increase in the number of patches (Figure 4-11b).



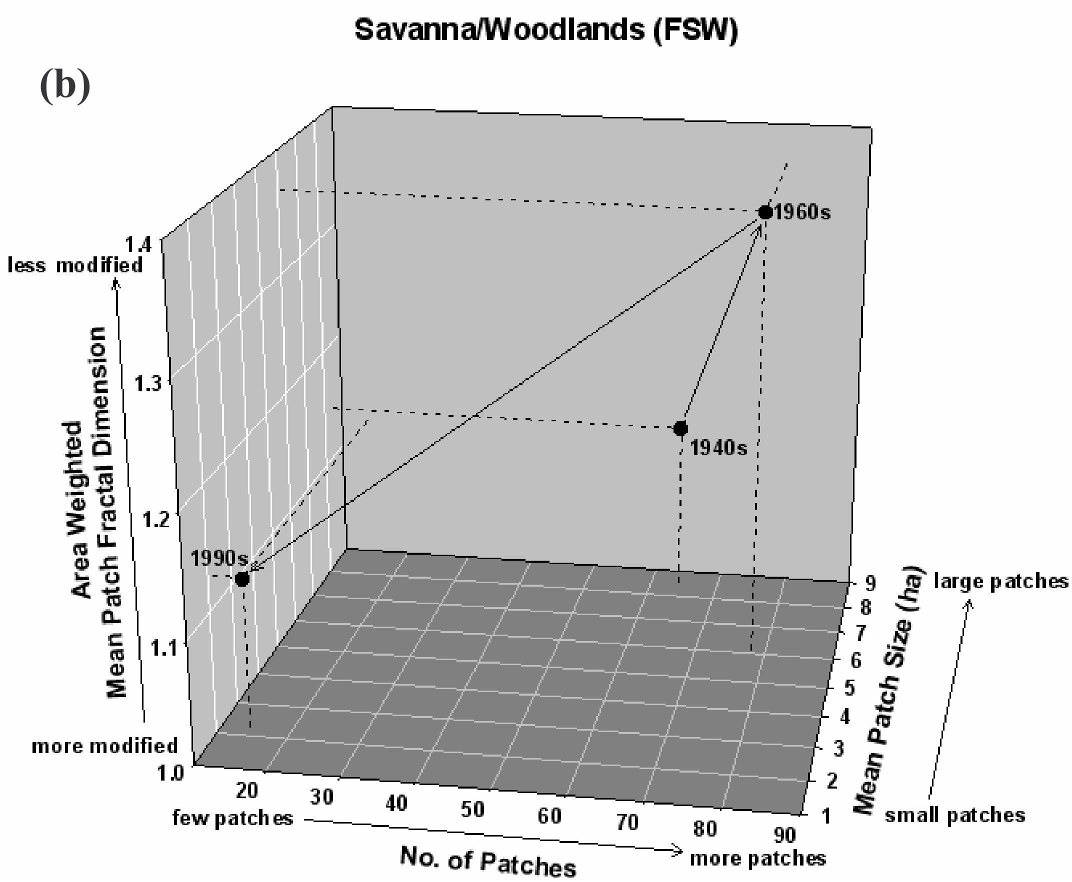


Figure 4-11: 3D landscape metrics space for (a) deciduous forest, and (b) savanna/woodlands at EFMO north showing the magnitude and direction of change

Between the 1960s to the 1990s a decline in all landscape parameters was observed, however, when these data were examined in conjunction with the change detection matrix for this time period, it was noted that 436 ha of savanna/woodlands was converted to deciduous forest. This trend supports concerns of NPS management that open woods (savanna) maintained by periodic wildfire are being replaced by more dense forest types in the absence of fire.

Bottomland forest and bottomland woodland showed opposing trends. A general decline in all landscape parameters of bottomland forest was accompanied (Figure 4-12a), in large part, by an increase in those parameters for bottomland woodland (Figure 4-12b). When examined with relation to the change detection imagery, it was observed that bottomland forest canopies were thinning and becoming bottomland woodland in subsequent years. This trend was more evident between the 1940s-1960s, where the number of patches of bottomland woodland increased along with the mean patch fractal dimension, indicating that several, irregular shaped patches were occurring in the landscape. Between 1960s-1990s, these patches had a lower mean patch fractal dimension because the construction of roads and railroads in the southern portion of the study area regularized adjacent forest boundaries.

Changes in pasture and cropland can be affected by management decisions made in response to changing natural or economic environments. In general, farm operators control their livelihood in the best manner they can by responding to changing conditions including climate variation, commodities market cycles, government policy changes and subsidy revisions. Pasture and cropland are the largest of the assets contained in a farm business that can be allocated to different methods of production to affect yearly income.

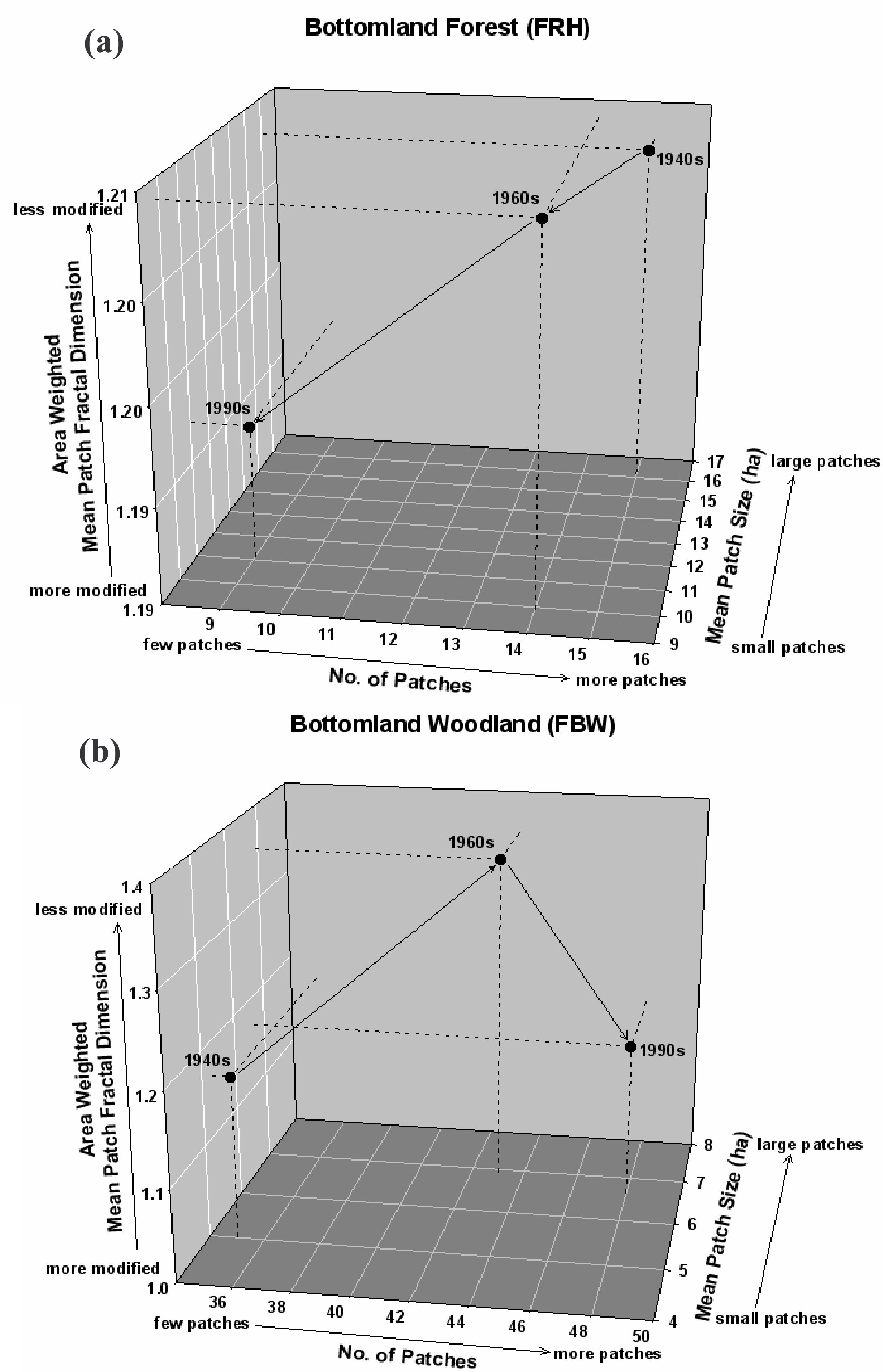


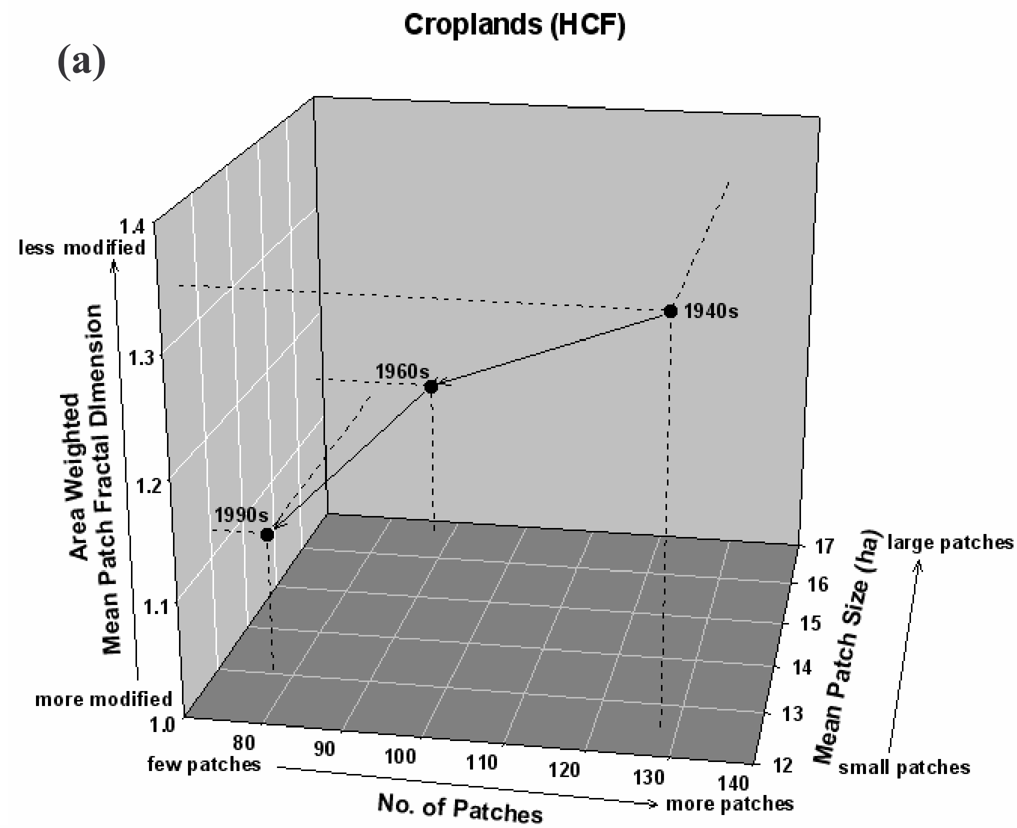
Figure 4-12: 3D landscape metrics space for (a) bottomland forest, and (b) bottomland woodland at EFMO north showing the magnitude and direction of change

For example, if market conditions favor livestock production with higher income returns, farmers will divert lands currently used for row crop production to a pasture usage by planting forage varieties that offer more lucrative financial returns. In other cases, the USDA crop subsidies may offer land managers the opportunity to stabilize or increase net income, leading to the transformation of tillable land that was being used for pasture to be converted to the specific cash crops (e.g., corn). Cropland and pasture showed similar pattern, with the exception of their mean patch size had increased for both categories, implying a consolidation of patches. In general, the number of patches and total class area declined for cropland (Figure 4-13a), while the areas of pasture increased, albeit with a decline in the number of patches (Figure 4-13b).

South Unit

Land cover classes including deciduous forest, bottomland forest, bottomland woodland, upland scrub, bottomland croplands, and pasture showed high temporal change in their number of patches, patch size, and fractal dimension (Table 4-2) compared to other classes and are, therefore, examined in 3-D landscape pattern space. For example, deciduous forest experienced a net increase of 96 hectares in their mean patch size and net decrease of 38 patches over 60 years indicating decrease in fragmentation and increase in clumpiness. In contrast bottomland forest experienced a net decrease of 22 ha in patch size and 14 patches indicating increase in fragmentation.

(a)



(b)

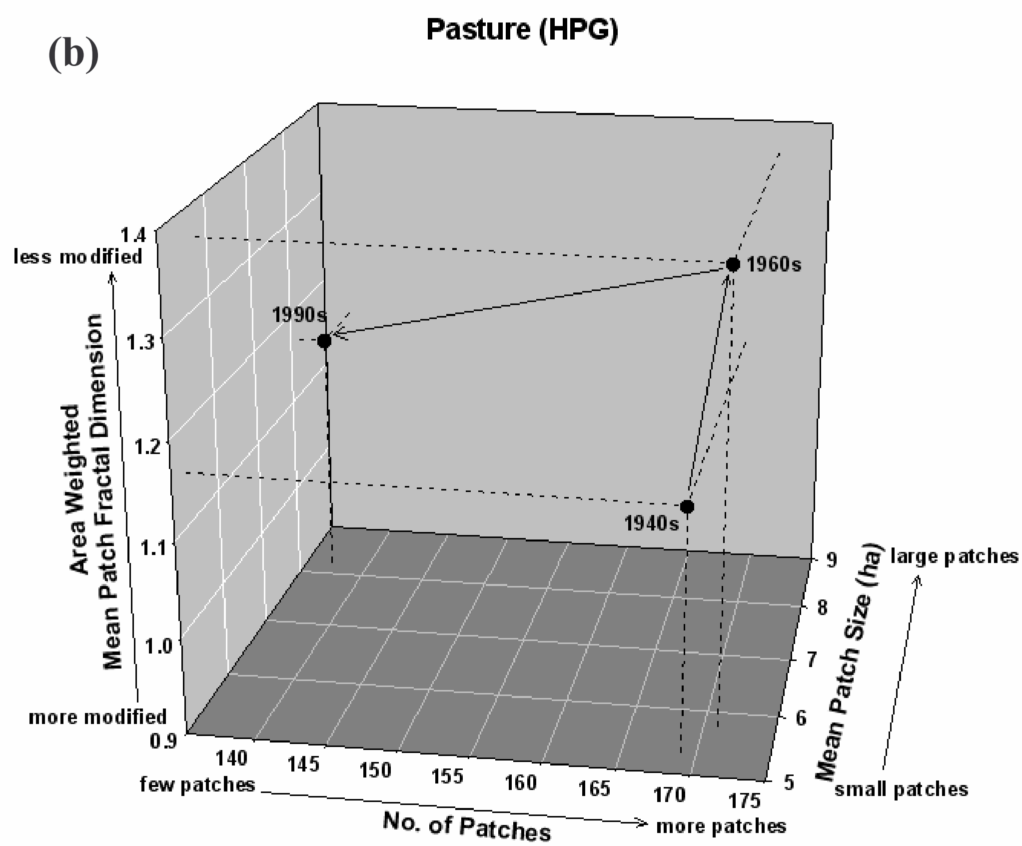


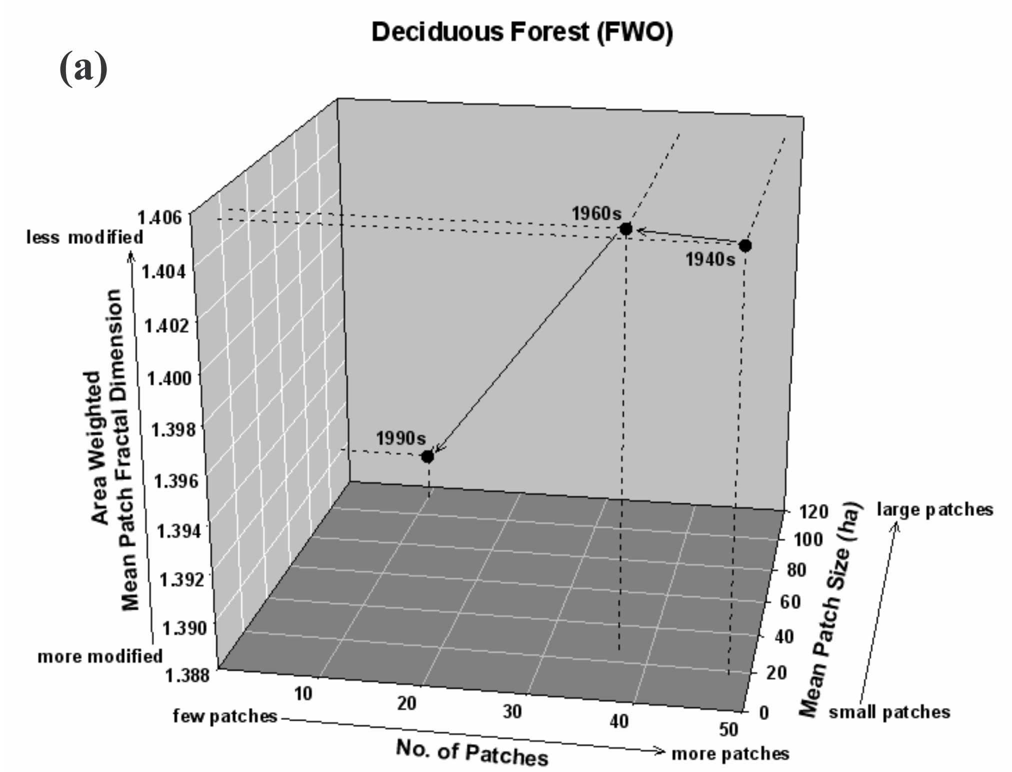
Figure 4-13: 3D landscape metrics space for (a) croplands, and (b) pasture at EFMO north showing the magnitude and direction of change

Table 4-2: Landscape metrics of selected land cover categories at EFMO south unit

Year	No. of Patches	Mean Patch Size	Area Wt. Mean Patch Fractal Dimension
Deciduous Forest			
1940s	48	17.978	1.405
1960s	37	26.455	1.405
1990s	10	113.412	1.39
Bottomland Forest			
1940s	14	41.338	1.4
1960s	28	18.27	1.442
1990s	28	19.168	1.407
Bottomland Woodland			
1940s	26	1.931	1.381
1960s	21	2.123	1.405
1990s	18	2.264	1.395
Upland Scrub			
1940s	19	1.7	1.363
1960s	38	1.53	1.422
1990s	14	0.589	1.452
Bottomland Croplands			
1940s	12	7.296	1.344
1960s	17	4.367	1.36
1990s	15	3.665	1.318
Croplands			
1940s	31	22.122	1.361
1960s	35	16.967	1.375
1990s	35	19.038	1.347
Pasture			
1940s	71	2.244	1.403
1960s	74	1.77	1.399
1990s	16	1.993	1.347

The natural landscape metrics include deciduous forest, bottomland forest and upland scrub. From 1940s – 1990s there was an increase in deciduous forest whereas bottomland forest and bottomland woodland showed a decline. Deciduous forest mainly gained from savanna, croplands, pasture and upland scrub. Some bottomland forest lost to rivers and streams which may be due to the fact that south unit of EFMO is located within the Mississippi River bottomland and is bordered to the north, south and east by bottomland forests, marshes, wetlands and braided river channels. The center of the Sny-Magill unit is within 1,000 meters of the main channel of the Mississippi and so being located in the flood plain would be sensitive to small changes in the water level of the river. Any elevated river levels tend to inundate marshes and wetlands such as those dispersed in the bottomland forests between the park and the main channel. By comparing the Sny Magill 1940 land use/land cover classification to later time periods it can be observed that waters from the Mississippi river cover less area than in the 1960s and 1990s. The result would be some of the lowest bottomland forest would be flooded, changed to a river classification in the 1960s and more for the 1990s.

Bottomland woodland lost to bottomland forest because of canopy thickening. For deciduous forest the number of patches decreased from 48 to 10 and there was remarkable increase in mean patch size which indicated a reduction in fragmentation (Figure 4-14a). Bottomland forest showed an increase in the number of patches and a decrease in mean patch size implying increased fragmentation of that land cover class (Figure 4-14b). Upland scrub lost primarily to deciduous forest, which is indicative of forest succession. Both the number of patches and mean patch size for upland scrub decreased from 1940s to 1990s (Figure 4-15). An interesting observation was the increase in deciduous forest while bottomland forest decreased. This was because savanna/woodlands (thinner canopy) and upland scrub had converted to deciduous forest whereas bottomland forest had become inundated by the widening of Mississippi river during the 60 years.



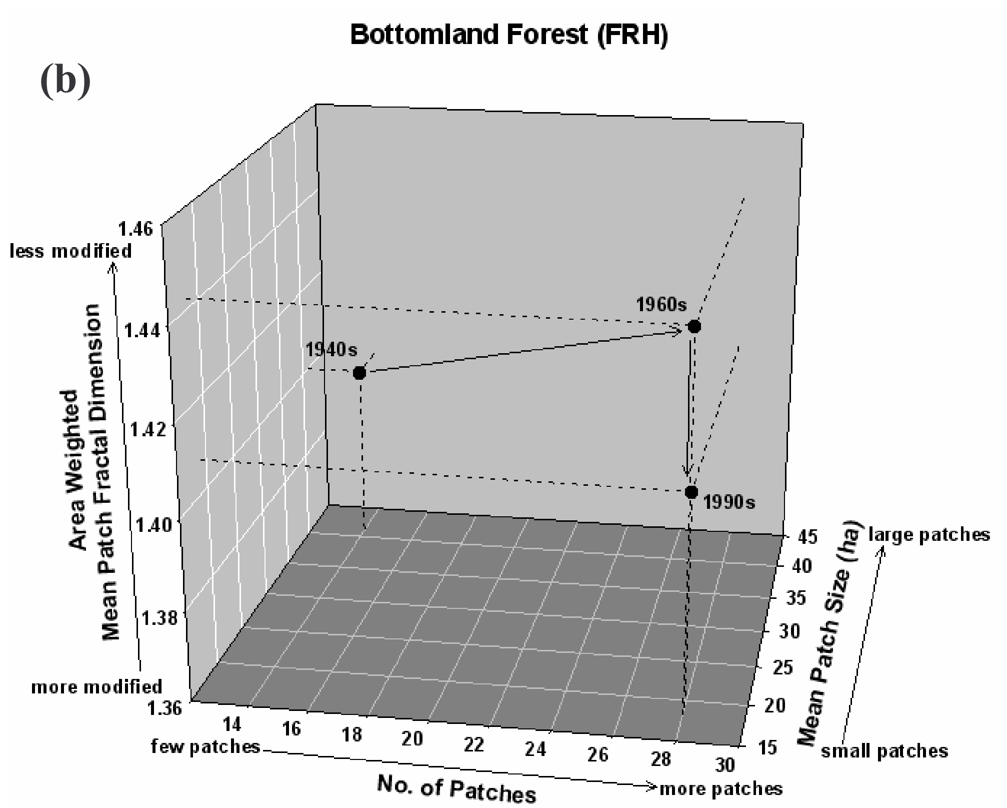


Figure 4-14: 3D landscape metrics space for (a) deciduous forest, and (b) bottomland forest at Sny Magill showing the magnitude and direction of change

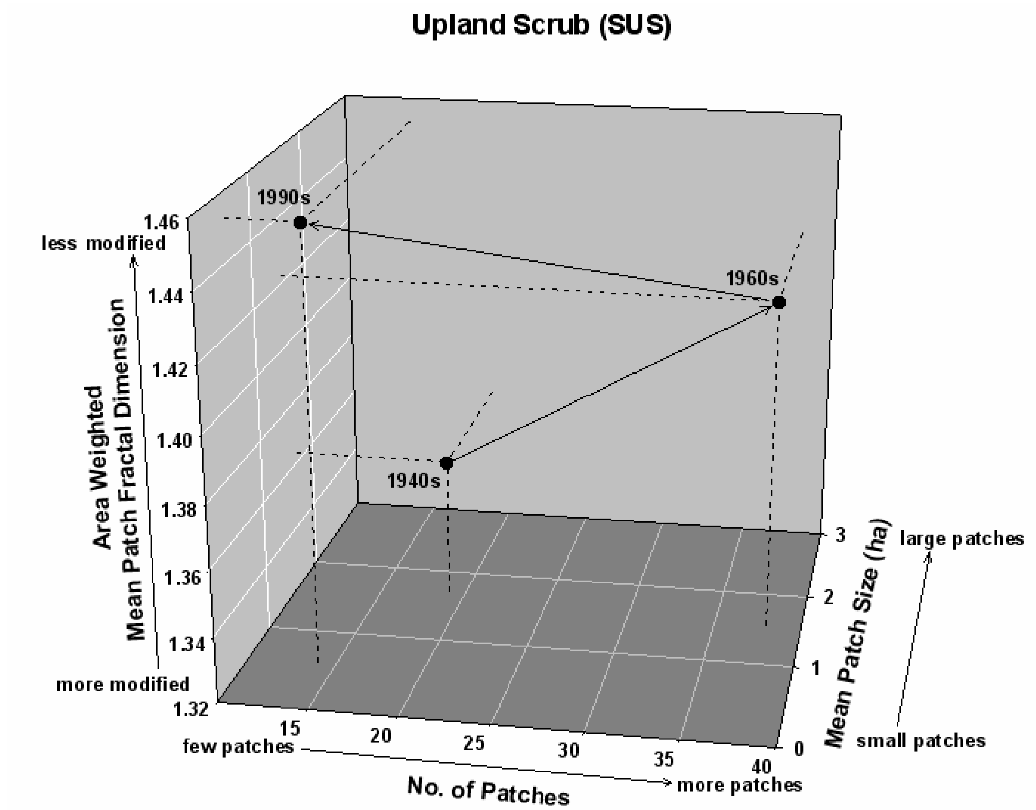


Figure 4-15: 3D landscape metrics space for upland scrub at Sny Magill showing the magnitude and direction of change

Agricultural landscape metrics for bottomland croplands, croplands, and pasture categories showed differing trends. Bottomland cropland showed an increase in number of patches between the 1940s-1960s, though mean patch size decreased by half (Figure 4-16a). However, by the 1990s few patches remained which were concentrated around Sny Magill Creek. Overall croplands exhibited a consistent trend. A slight decline in their area (1940s-1960s) was followed by a small increase in the 1990s. Their mean patch size decreased along with mean patch fractal dimension (Figure 4-16b) as patches became regular in shape. Pasture showed significant decrease in number of patches and became more regular in shape with only a few scattered patches remaining in 1990s (Figure 4-17).

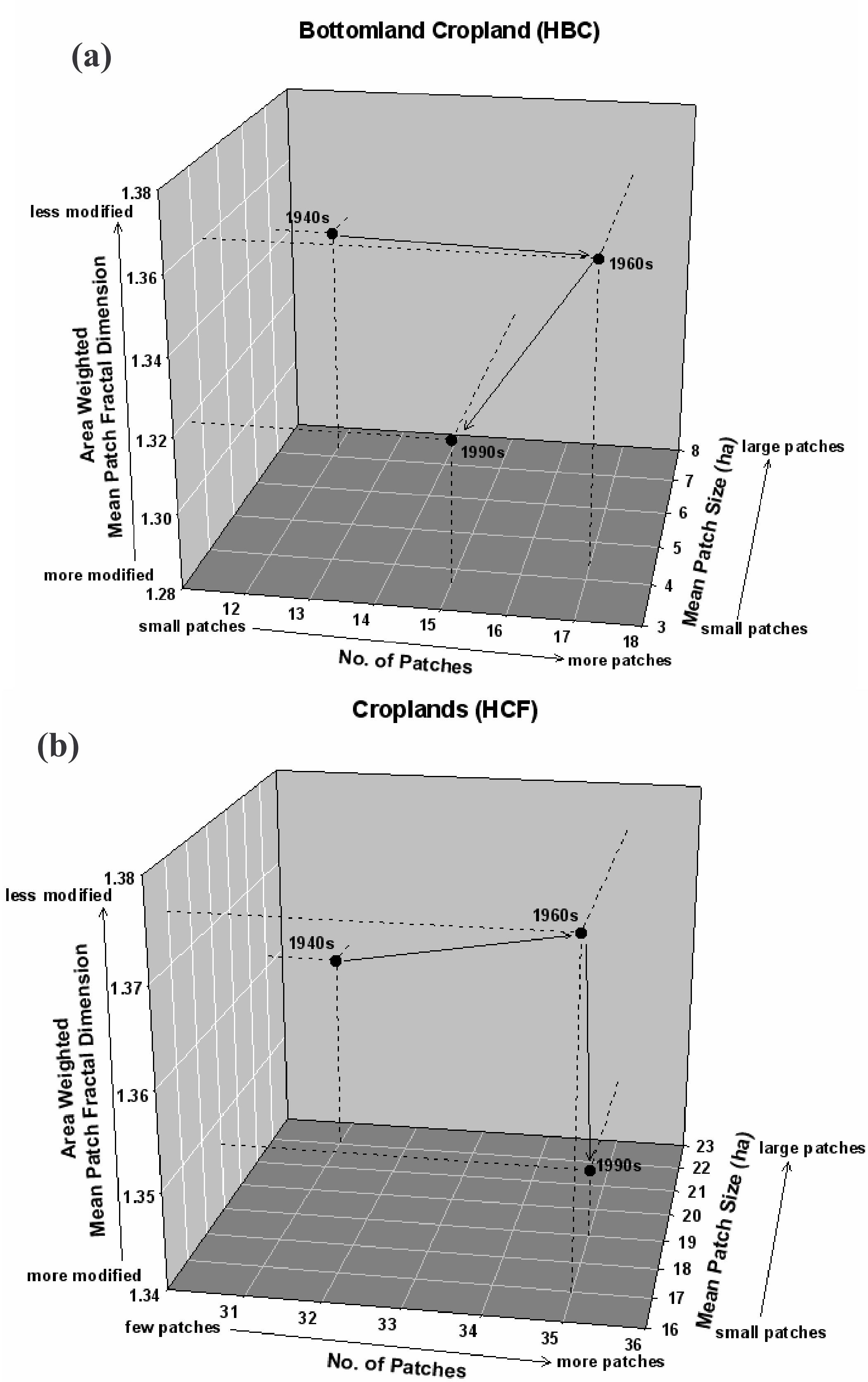


Figure 4-16: 3D landscape metrics space for (a) bottomland cropland, and (b) cropland at Sny Magill showing the magnitude and direction of change

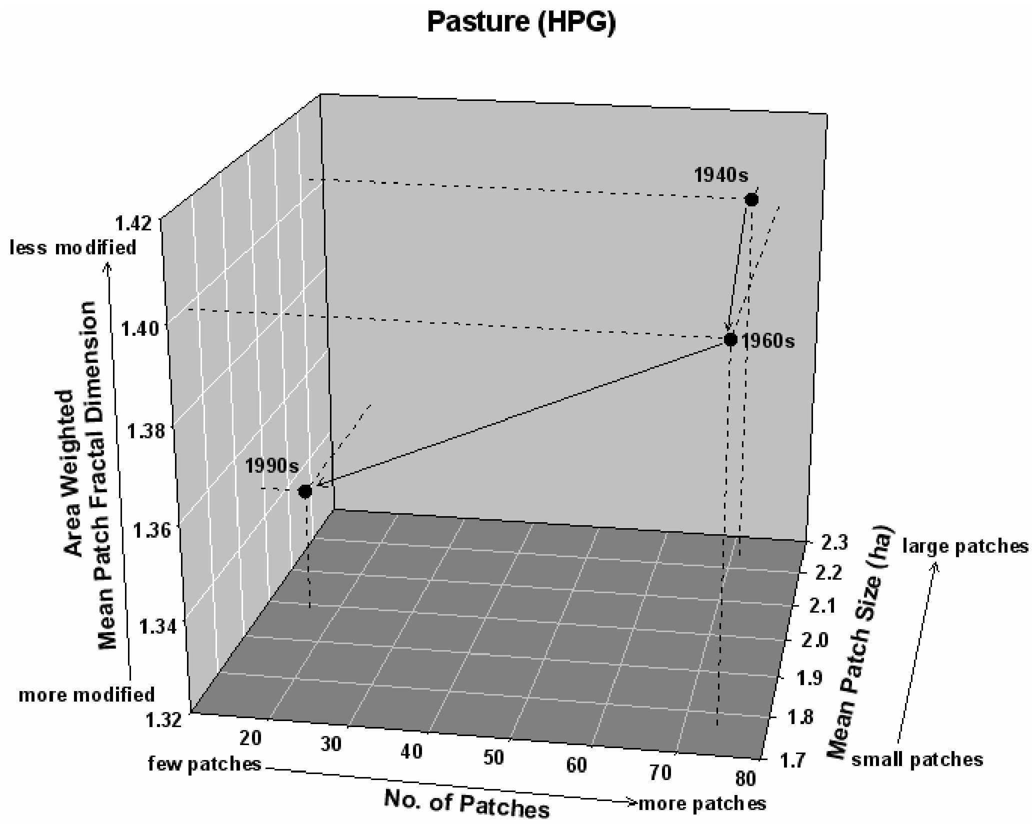


Figure 4-17: 3D landscape metrics space for pasture at Sny Magill showing the magnitude and direction of change

Bottomland cropland mainly lost to deciduous forest and bottomland woodland. The primary reason for the change in the bottomland cropland classification at the south unit of EFMO is a decrease in tillage area by farmers along the tributary (Yellow river) that flows through the park. In the bottomlands of Sny Magill Creek two fields interpreted as row crops in the 1940s were classified as woodlands in the 1960s. A similar observation was made for two other fields that went from bottomland cropland to deciduous forest. Potential reasons for such change could be change of goals for land management or change in farm ownership. For example, if a field proves to be hard to cultivate and plant over a period of time, the land owner may decide the field is not worth the expense to plant and harvest. In other cases a field may be eligible for federal crop subsidies over a period of time and then become ineligible because of changing rules for subsidy qualification. After the subsidy stops an owner may not cultivate the cropland and allow it to be a pasture that eventually converts to woody species in the plant communities.

4.1.4. Discussion

When evaluating change across several decades, it is important to be aware of the impacts that alterations in governmental land management policy can have. Rindfuss and Stern (1998) state that land use changes are often reflective of abstract variables such as governmental policies, market mechanisms, social customs, land tenure rules, and distributions of wealth and power. As described earlier, some of the changes in the EFMO area were indicative of precisely such issues (e.g., fire management policies and USDA strategies).

Further examples of such influences are revealed in the 1936 USDA policy that focused on decreasing soil erosion losses from agricultural lands in the U. S. Practices such as field reshaping for terrace formation combined with contour seedbed tillage and planting were some of the land management strategies implemented to slow the rate of water runoff and decrease topsoil losses (example Figure 4-18). The USDA provided monetary incentives in the form of cost-share payments to land owners to offset their expenses for reshaping their fields, which in turn decreased the mean patch fractal dimension for croplands from 1940s-1990s.

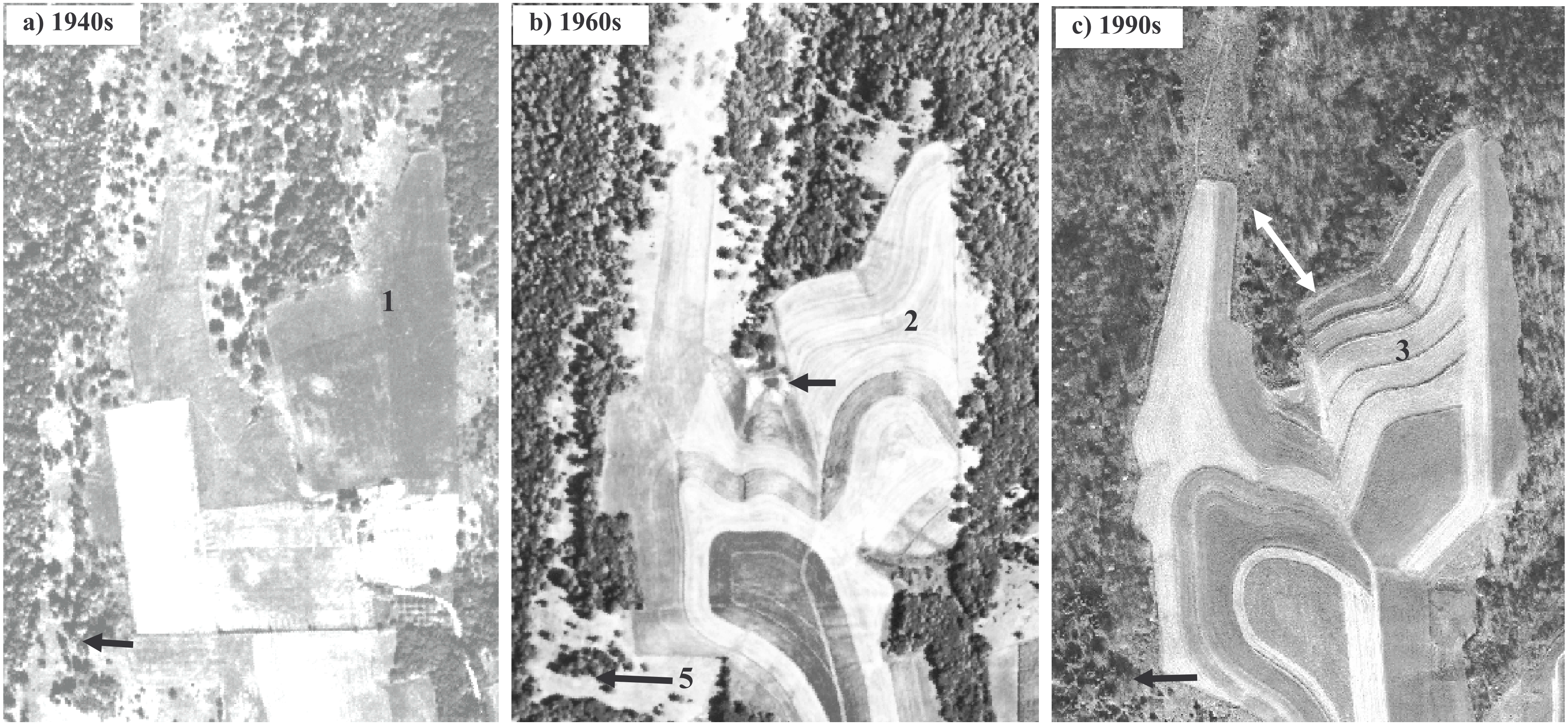


Figure 4-18. Comparison of spatial change at an agricultural field lying adjacent to a deciduous forest boundary, between the three time periods. (a) In the 1940s the field is dominated by straight line cultivation and surrounded by pasture (1). (b) In the 1960s, newer management practices are evident i.e., contour tillage, field terracing and a new farm pond in the center of the scene (2). (c) The 1990s image shows matured contour farming practices within the well defined (fenced) field (arrows) while scrub growth is evident in old pasture at the top of scene (3). Pasture vegetative succession to scrub is illustrated by the clean look of the (a) 1940s woodland pasture bordering the west side of the cultivated field (4). In the 1960s (b), that area has a rougher texture (5) and by 1990s (c) it is evident that scrub and mature trees have filled in the canopy (6).

Another facet of the soil erosion control policy encouraged land owners to create water impoundments by building earthen berms in the path of precipitation runoff. Cash assistance payments were made when land operators cooperated with the USDA for these projects. Consequently, large numbers of farm ponds were constructed between the 1960s-1990s in the vicinity of EFMO and were manifest in the change detection matrix as well as the landscape metrics.

An additional manifestation of changes in policy pertains to the fact that in the early part of the twentieth-century, considerable logging of hardwood deciduous forests occurred in the north-eastern portion of Iowa. Many of the plots and fields cut into the forests within the EFMO area and were easy to interpret from the 1940s aerial photography because of their distinctive regular shapes. In the later time periods, patterns of floral succession were evident - plant maturation to scrub (low or interrupted canopy <60% cover) and forest canopy (>60% cover) could be observed at the edges of some plots. In some areas, old forest cuts were completely recovered, while in other cases the deforested areas remained clear-cut because of cropping and pasturing land management practices. These landscape patterns, interpreted from the photographs, and described by the metrics provide an insight into the changing socio-economic processes and policies as well as the anthropogenic influences over the 60 year period. Within the park boundaries there has been very little change; however, its surrounding area has borne witness to varying intensities of land use transitions and modifications influenced largely by external drivers.

4.2. Pipestone National Monument

4.2.1. Classification and Image Interpretation

Fifteen different land cover categories were identified at PIPE. Final land cover classification map showed major portion of the parks are covered by croplands (Figure 4-19 & 4-20). This dominant land cover occupied > 80% of the total land at PIPE for all 60 years from 1940s to 2000. Pasture and urban areas were found to be the next dominant land covers. Land cover classes including croplands, other croplands, pasture, commercial, farmsteads, residential, and urban showed high temporal change in their class area compared to other classes. From 1940s to 1990s, croplands experienced a net increase of 1,571 hectares, which indicate a major change in agricultural practices.

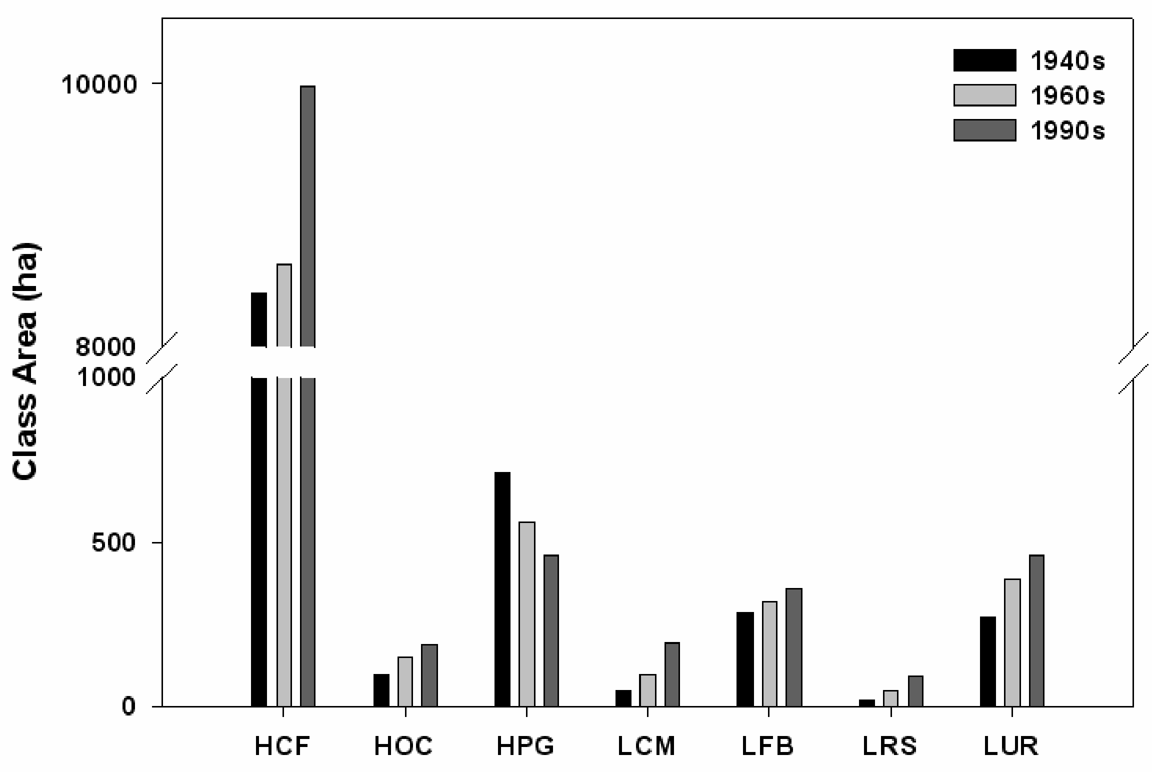


Figure 4-19: Total area of different land cover classes at PIPE

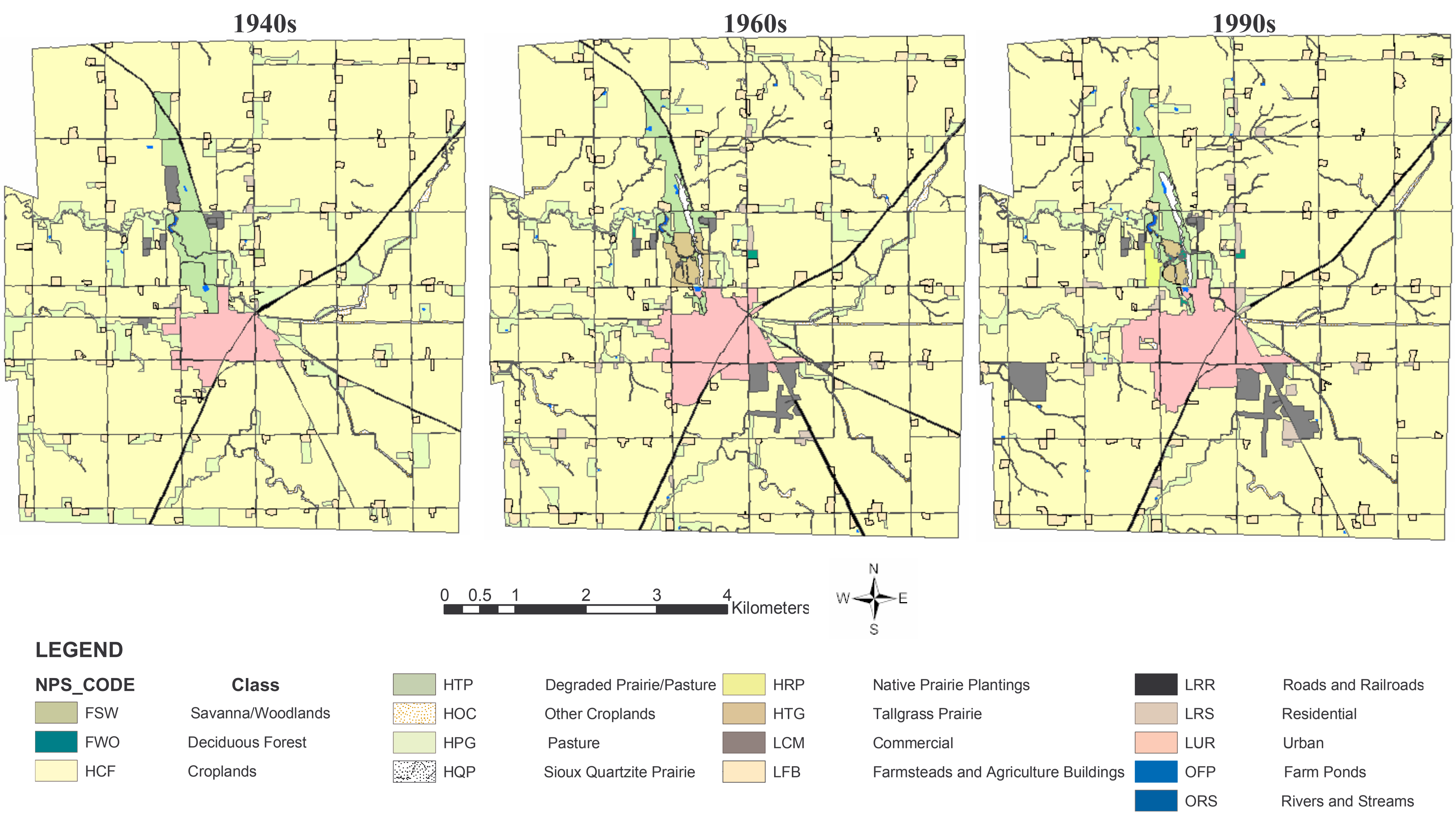


Figure 4-20: Land use/land cover classification maps of PIPE for the 1940s, 1960s, and 1990s derived from the image interpretation process

4.2.2. Change detection

Major changes at PIPE for the period 1940s-1960s comprise mainly of the loss of cropland to pasture and urbanization. For example, commercial area increased from 49 ha to 94 ha while substantial areas of pasture were converted to cropland. Because of reclassifying some areas of degraded prairie/pasture to Sioux quartzite prairie, pastureland exhibited a loss of total area (Figure 4-21).

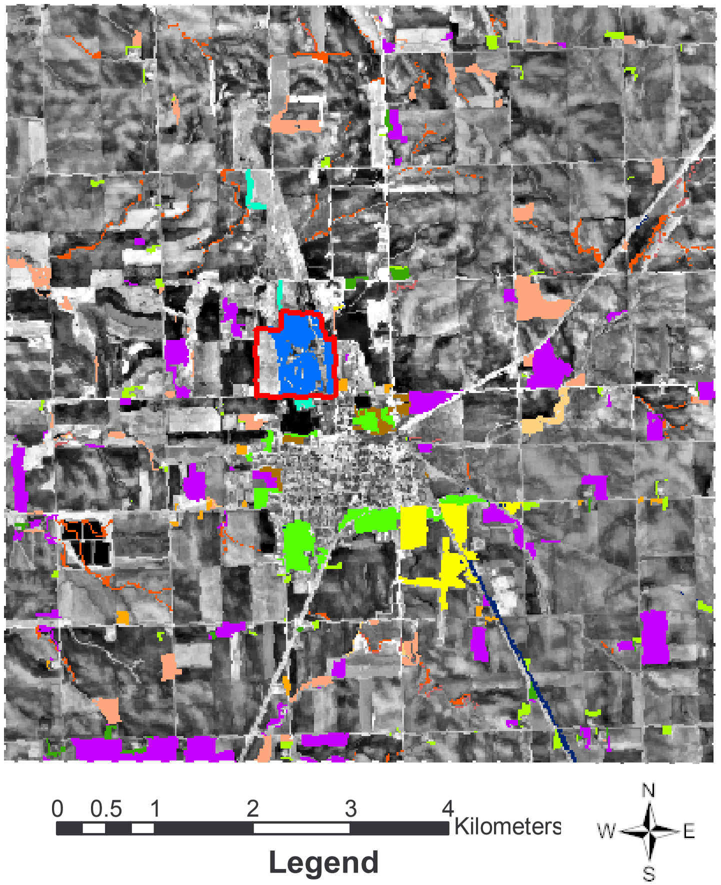
During the period 1960s-1990s, 60% of the savanna woodlands matured into deciduous forest. At the same time pasture areas continued to lose ground mainly through conversion to cropland and/or degraded prairie/pasture. Continued development of roads and railroads and agricultural buildings caused losses of cropland and pasture areas (Figure 4-22).

From an overall perspective 1940s-1990s, there was an increase in urbanization through infrastructure development, commercial, and residential. A general decline in pasture areas was accompanied by increases in cropland indicating changes in agricultural practices in the region (Figure 4-23).

4.2.3. Landscape Metrics

Land cover classes including croplands, other croplands, pasture, commercial, farmsteads, residential, and urban showed high temporal change in their number of patches, patch size and fractal dimension compared to other classes and are, therefore, examined in 3-D landscape pattern space (Table 4-3). For example urban areas experienced a net increase of 24 hectares in their patch size over 60 years which indicate a major urbanization.

Location of changes for highlighted classes in the table



Legend

- Park Boundary
- Croplands to Pasture
- Croplands to Other Croplands
- Croplands to Residential
- Croplands to Commercial
- Croplands to Farmsteads
- Croplands to Roads and Railroads
- Croplands to Urban
- Degraded Prairie/Pasture to Croplands
- Degraded Prairie/Pasture to Tallgrass Prairie
- Pasture to Croplands
- Pasture to Farmsteads
- Pasture to Urban
- Other Croplands to Croplands
- Other Croplands to Pasture

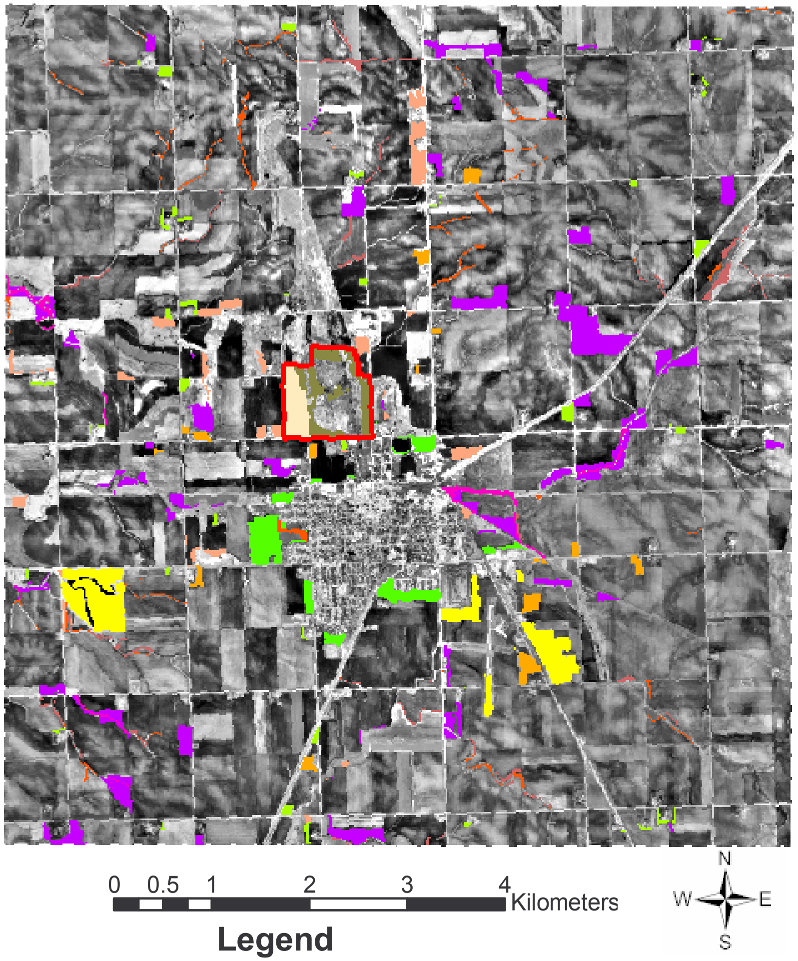
Pipe Stone Change Detection: 1940s-1960s (hectares)

1960s (columns); 1940s (rows)

Class	FSW	FWO	HRP	HCF	HDP	HPG	HOC	HQP	LRS	LCM	LFB	LRR	OFP	ORS	LUR	HTG
FSW		4														
FWO																
HRP																
HCF	1				4	149	76		18	74	52	19	1		86	2
HDP	4			13		4		22		1		1	1		9	71
HPG		1		305	1		5		8		23	2			21	
HOC				14		17										
HQP																
LRS				3											4	
LCM				14	14	4										
LFB				23		14			13	1					5	
LRR										1					3	1
OFP																
ORS																
LUR				1		2					4					
HTG																

Figure 4-21: Selected land cover change for PIPE (1940s-1960s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1960s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Legend

- Park Boundary
- Croplands to Native Prairie Plantings
- Croplands to Pasture
- Croplands to Other Croplands
- Croplands to Residential
- Croplands to Commercial
- Croplands to Farmsteads
- Croplands to Urban
- Pasture to Croplands
- Pasture to Other Croplands
- Other Croplands to Croplands
- Tallgrass Prairie to degraded Prairie/Pasture

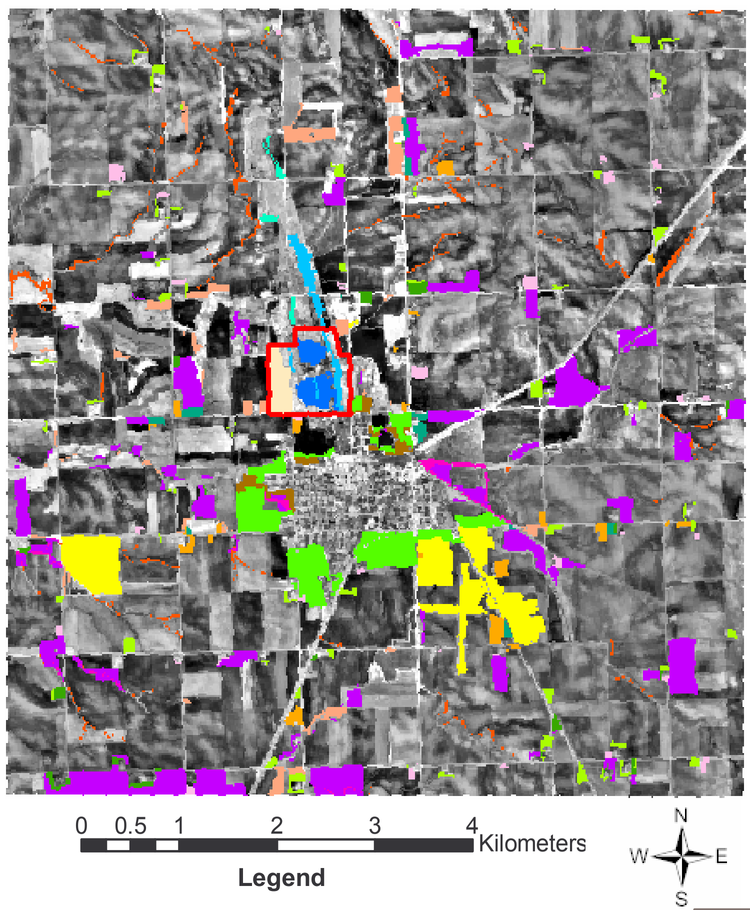
Pipe Stone Change Detection: 1960s-1990s (hectares)

Rows: 1960s; columns: 1990s

Class	FSW	FWO	HRP	HCF	HDP	HPG	HOC	HQP	LRS	LCM	LFB	LRR	OFP	ORS	LUR	HTG
FSW		4			1											
FWO	1								1							
HRP																
HCF			24		11	60	35		35	96	36				59	
HDP		1		8		7		5	1	2				1	1	
HPG				240	9		22		6		2				9	
HOC				38		1				6						
HQP					2											
LRS											6				5	
LCM				1		3									4	
LFB				28		2			2						6	
LRR				32	4	2	1			4	1				1	
OFP																
ORS																
LUR				4		1			10							
HTG		2	1		39			4								

Figure 4-22: Selected land cover change for PIPE (1960s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1960s-1990s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Legend

- **Park boundary**
- Croplands to Native Prairie Plantings
- Croplands to Pasture
- Croplands to Other Croplands
- Croplands to Residential
- Croplands to Commercial
- Croplands to Farmsteads
- Croplands to Urban
- Degraded Prairie/Pasture to Croplands
- Degraded Prairie/Pasture/Sioux Quartzite Prairie
- Degraded Prairie Pasture to Tallgrass Prairie
- Pasture to Croplands
- Pasture to Other Croplands
- Pasture to Residential
- Pasture to Farmsteads
- Pasture to Urban
- Farmsteads to Croplands

Pipe Stone Change Detection: 1940s-1990s (hectares)

1990s (columns); 1940s (rows)

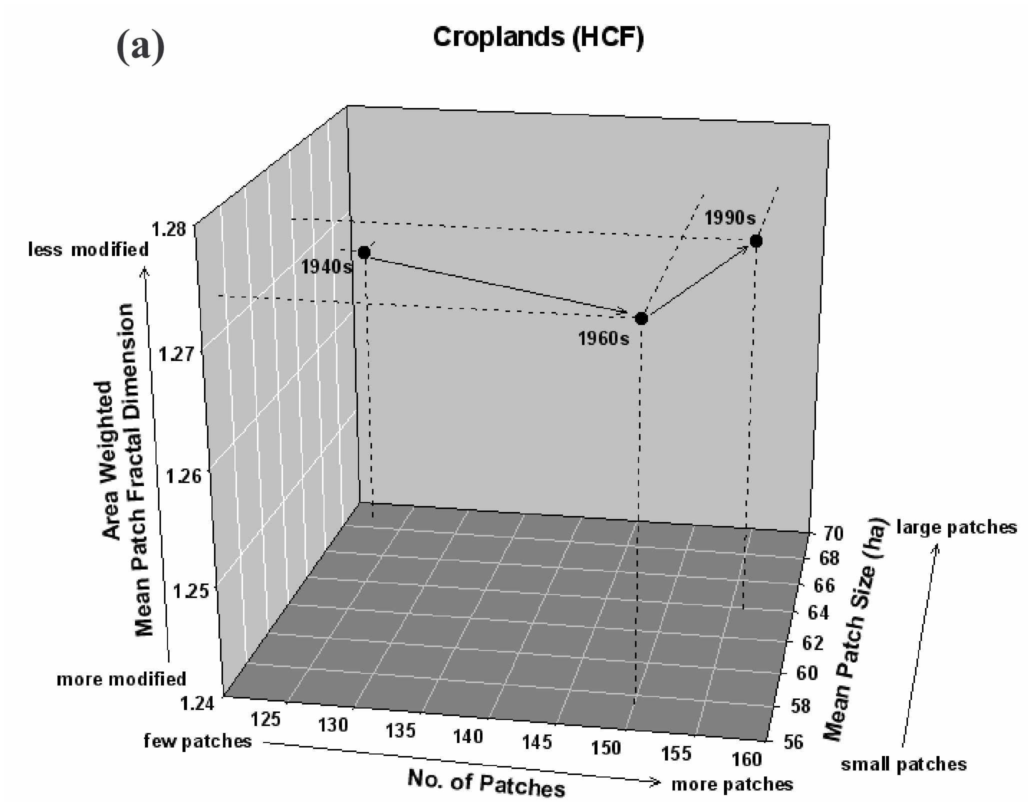
Class	FSW	FWO	HRP	HCF	HDP	HPG	HOC	HQP	LRS	LCM	LFB	LRR	OFP	ORS	LUR	HTG
FSW		3							1							
FWO																
HRP																
HCF	1		24		8	87	79		40	173	77	1	1		149	
HDP		6	1	8		6		28		1	1	1	1	1	9	29
HPG	1			406	4		20		20		26				24	
HOC																
HQP				34		2										
LRS															2	
LCM				16	7	5			1						1	
LFB				42		9			14	1					6	
LRR				20	4	2			2	1					2	
OFP																
ORS																
LUR						4										
HTG																

Figure 4-23: Selected land cover change for PIPE (1940s-1990s). Colors on the image indicate “from-to” change categories based on “natural” vegetation and the same color is highlighted in the change detection matrix (1940s-1990s), which quantify the amount of change in hectares.

Table 4-3: Landscape metrics of selected land cover categories at PIPE

Year	No. of Patches	Mean Patch Size	Area Wt. Mean Patch Fractal Dimension
Croplands			
1940s	122	68.937	1.267
1960s	150	57.499	1.273
1990s	156	63.982	1.274
Pasture			
1940s	76	9.340	1.351
1960s	87	6.420	1.371
1990s	66	6.986	1.382
Other Croplands			
1940s	34	2.893	1.520
1960s	51	2.984	1.540
1990s	65	2.870	1.570
Commercial			
1940s	8	6.183	1.282
1960s	14	6.758	1.314
1990s	15	13.006	1.324
Residential			
1940s	12	1.453	1.331
1960s	24	2.062	1.312
1990s	33	2.846	1.316
Urban			
1940s	10	26.841	1.306
1960s	14	27.762	1.305
1990s	9	50.859	1.282
Framsteads			
1940s	116	2.455	1.302
1960s	120	2.658	1.300
1990s	131	2.725	1.299

Croplands became fragmented because of the decrease in their mean patch size, and a significant increase in number of patches (122-156) from 1940s to 1990s (Figure 4-24a). Human influence based on mean patch fractal dimension remained the same throughout. Often there was an interchangeable shift between pasture and croplands because of new agricultural measures, however, the overall result was a loss of pasture and a decline in number of patches and mean patch size of pasture (Figure 4-24b). Other croplands showed increase in number of patches while mean patch size remained the same (Figure 4-25).



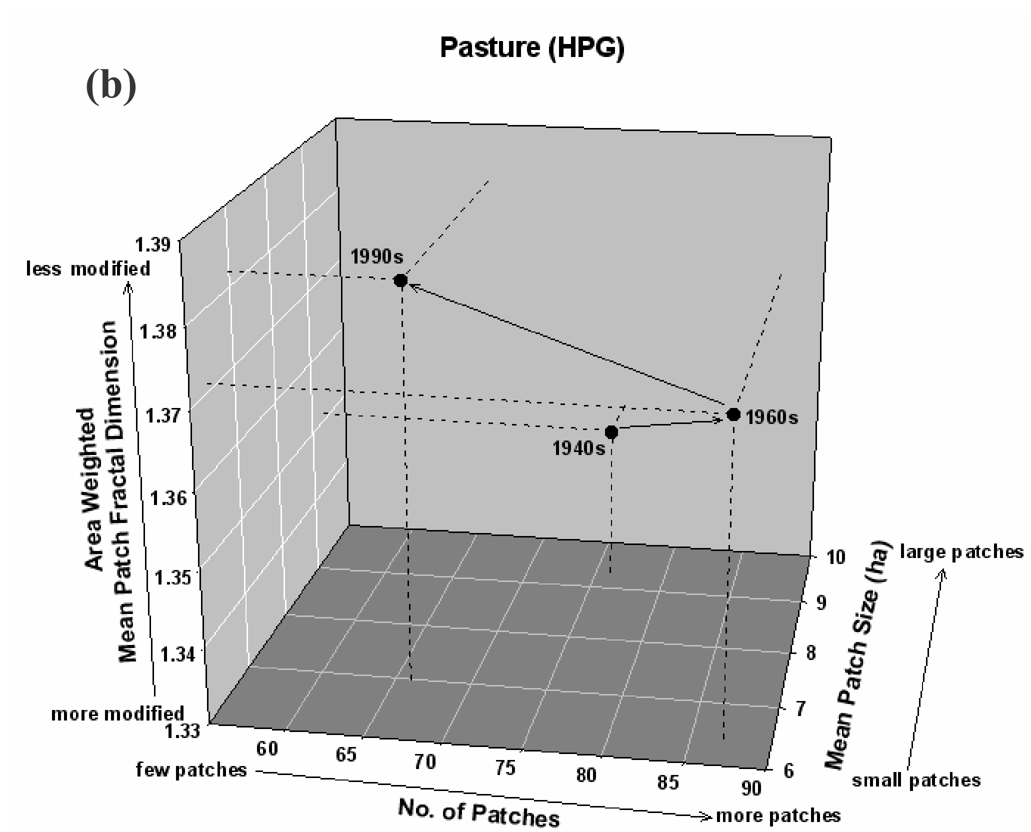


Figure 4-24: 3D landscape metrics space for (a) croplands, and (b) pasture at PIPE showing the magnitude and direction of change

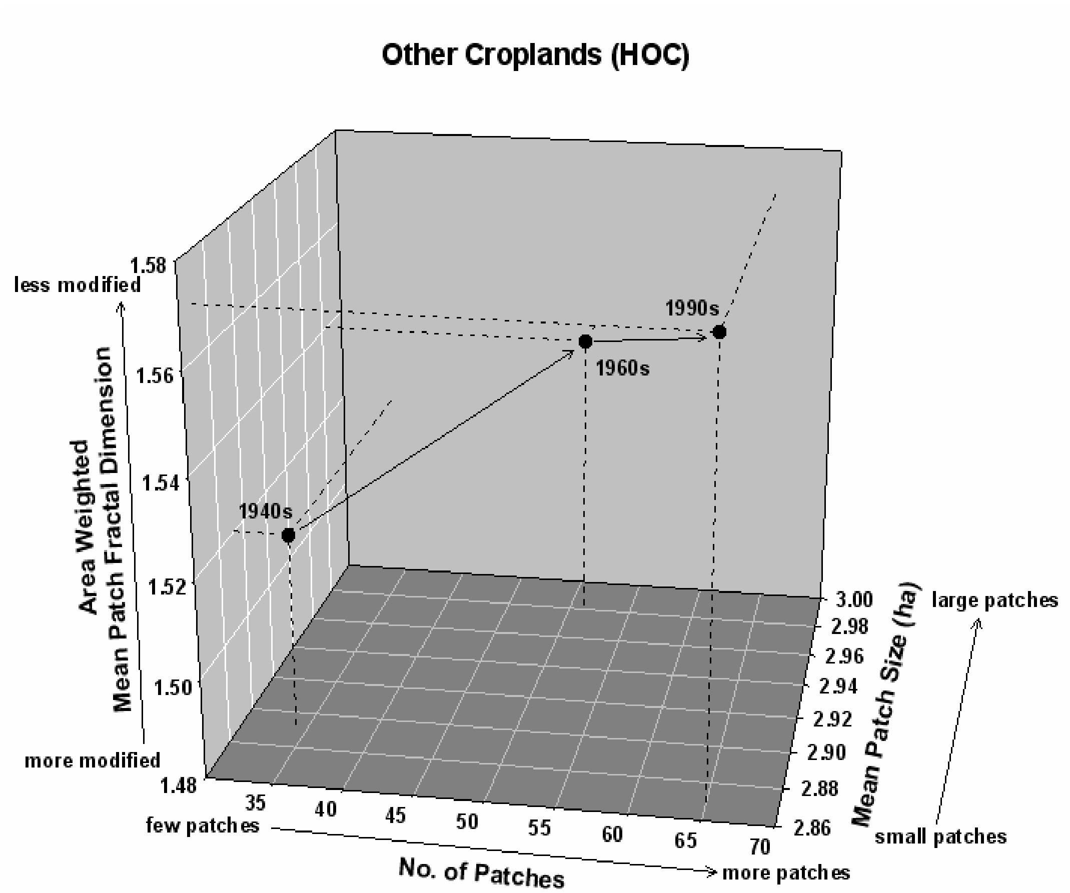


Figure 4-25: 3D landscape metrics space for other croplands at PIPE showing the magnitude and direction of change

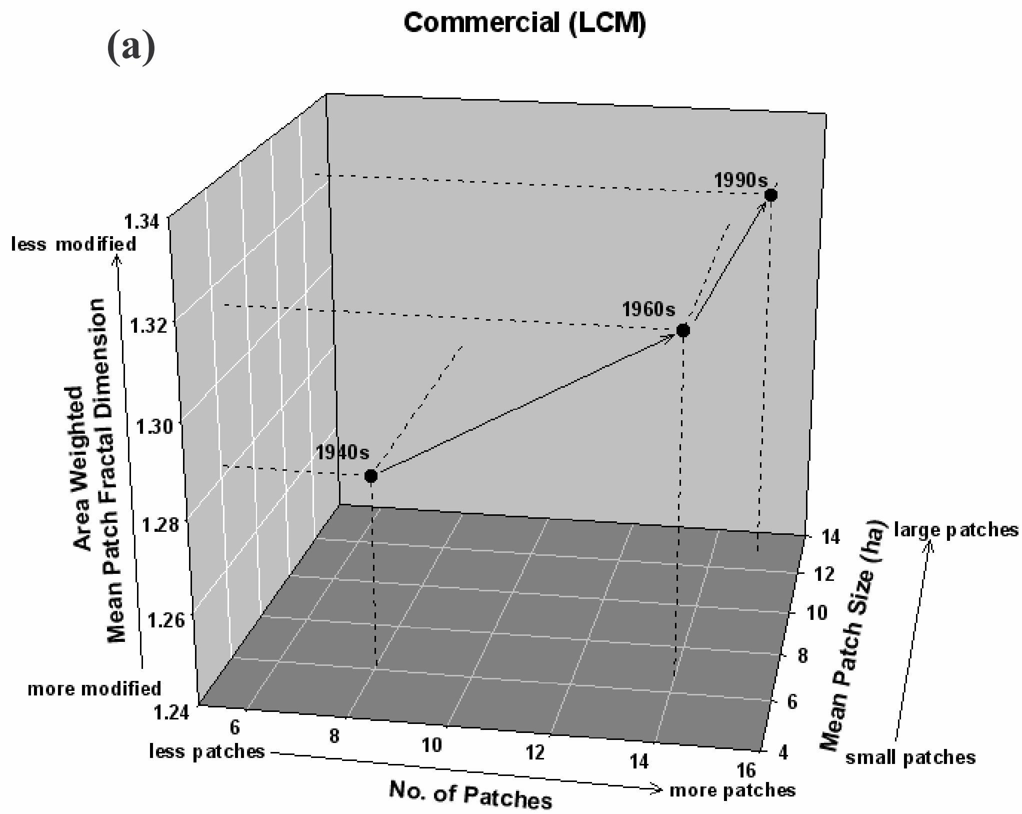
Very little "natural" vegetation was present around PIPE in any of the time periods. Deciduous forest (FWO) which was non-existent in the 1940s, had claimed a total of 10 ha by the 1990s, maintaining a patch size of 2.7 ha, though the number of patches had risen from 2 (1960s) to 14 (1990s). Mean patch fraction dimension of "natural" vegetation categories were ranged from 1.2-1.3, which was generally smaller than that recorded for EFMO or WICR. This is because of a flat topography and the dominance of human influence which would lead to areas having fairly regular shapes.

Commercial and residential showed similar trends i.e., increase in mean patch size and number of patches. Commercial doubled in their number of patches and mean patch size while residential doubled in their number of patches (Figure 4-26a & b). Urban areas dropped in their number of patches though mean patch size was doubled (Figure 4-27a), indicating an increase in the cohesiveness of formerly isolated patches of urban area. Urban and residential classes gained acreages from cropland because fields in proximity to residential areas were sold for development. Farmsteads showed an increase in number of patches i.e., an increase in farm buildings, which is due to significant growth of croplands in the area (Figure 4-27b).

4.2.4. Discussion

The majority of land use in the PIPE study area is dominated by agriculture. Pasture and cropland make up most of the areas used for production and an exchange between the two classes can occur as a result of several factors. Soil conservation goals, changes in economic subsidies for grain crops, changes in profit margins for land owners that can be realized in other categories of commodities are things farmers must consider when deciding how to get the most return from the land assets they control. For example, financial returns from participating in federal grain price programs intended to stabilize food commodity prices, producing grain for cash or realizing income from meat commodities produced from a combination of pasture and grain are some of the factors each land operator must consider when deciding the land use practices for the future.

(a)



(b)

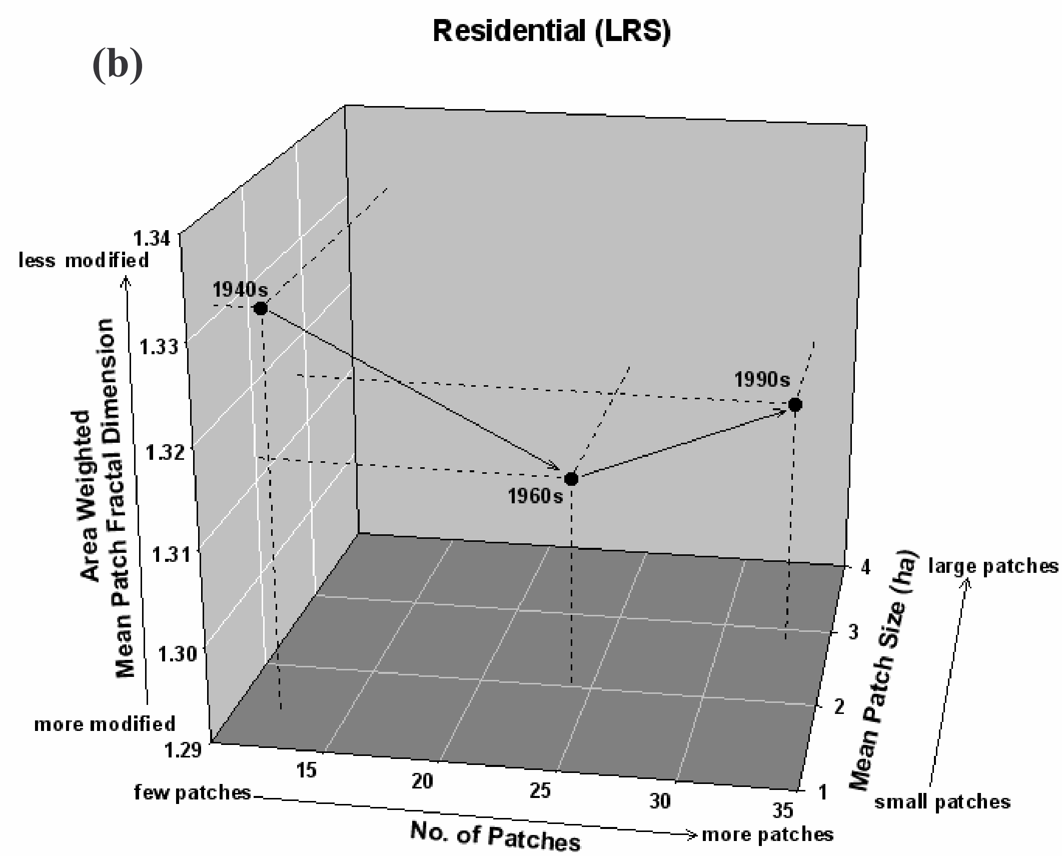
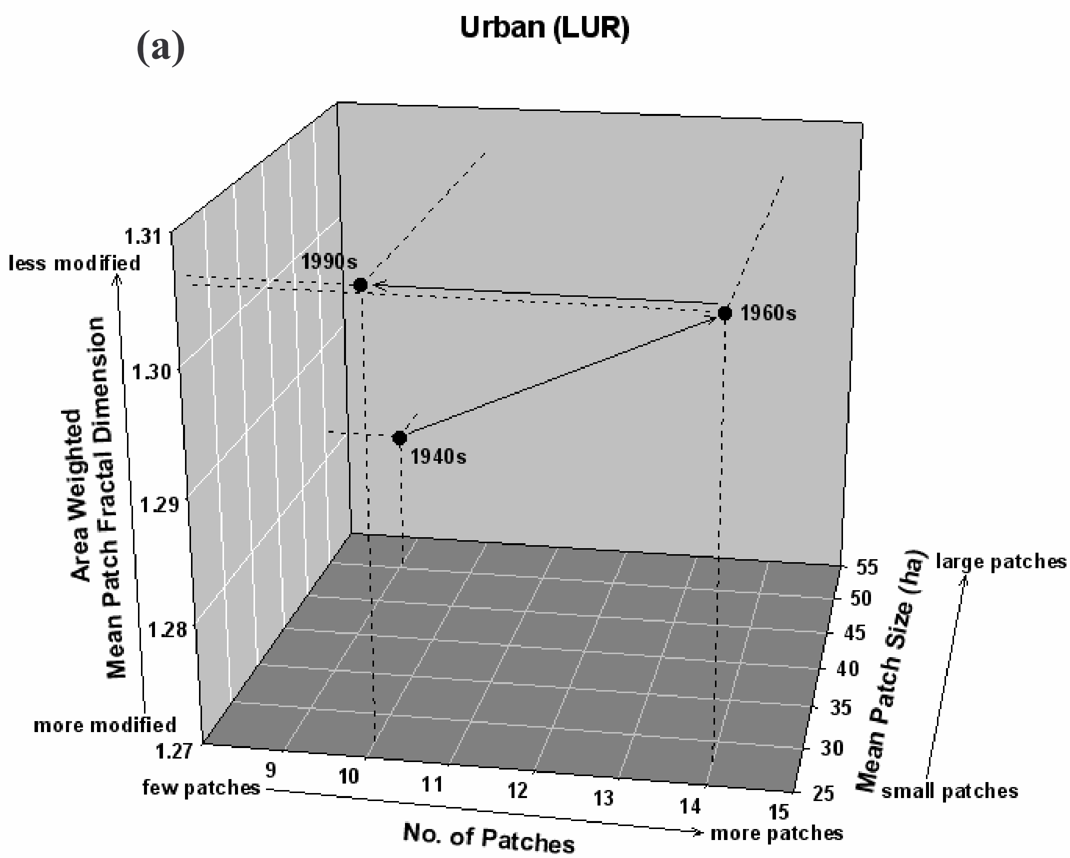


Figure 4-26: 3D landscape metrics space for (a) commercial, and (b) residential at PIPE showing the magnitude and direction of change

(a)



(b)

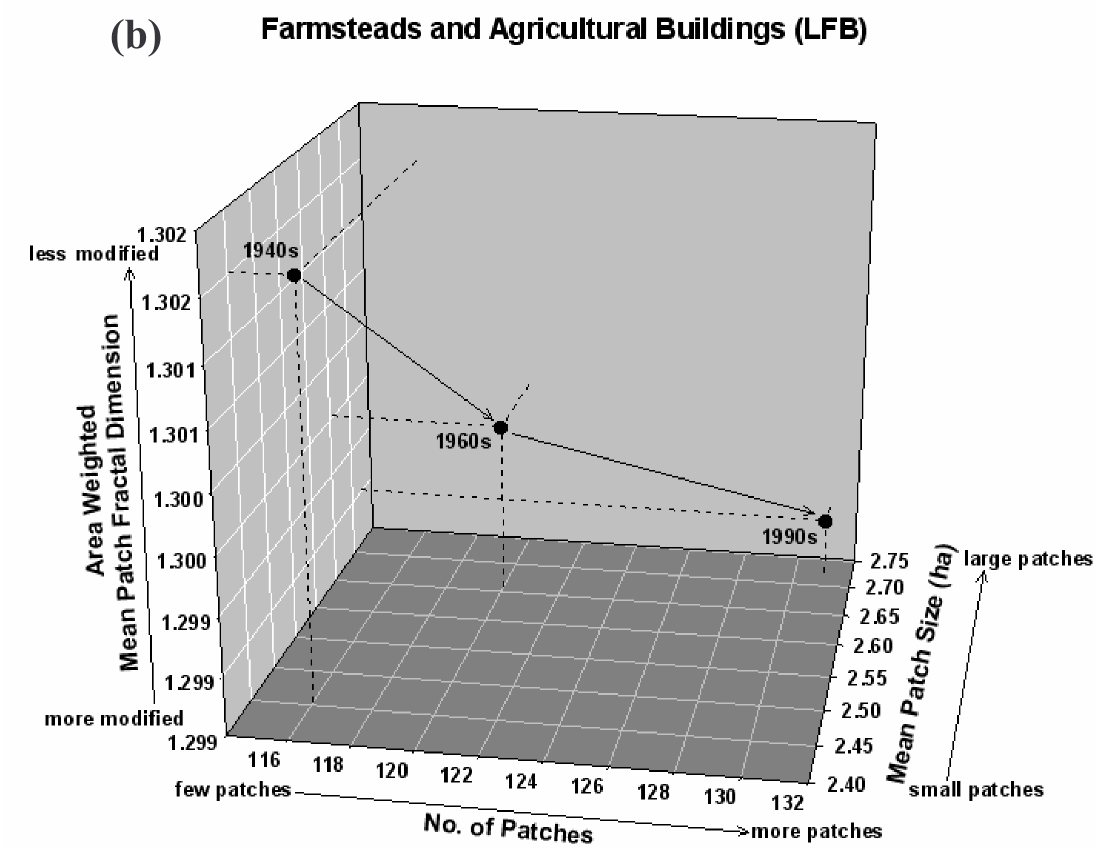


Figure 4-27: 3D landscape metrics space for (a) commercial, and (b) residential at PIPE showing the direction and magnitude of change

In the 1940s, more real estate in farms was devoted to pasture for meat producing livestock because of the added value gained by selling livestock compared to only marketing grain products. Also transportation of livestock products to markets may have been easier than moving bulk grain. In the 1960s through the 1990s, financial returns could have been increased from grain products through federal grain reserve and commodity price stabilization subsidy programs that became available to agricultural producers. So converting more pasture to croplands and participating in USDA programs may have been encouraged by net profit increases for agricultural operators.

Most cropland includes drainage patterns that may contribute to increased topsoil losses during runoff events from precipitation. When soil is eroded, farming operators can choose to leave the ditches and till around them, reshape the contours of the land to allow crop production to continue at these sites, or provide buffer zones set aside from annual tillage around the reshaped valleys to slow water and filter topsoil. Topsoil conservation policies that were begun at some time during the period of the this study encouraged land owners to develop buffer zones of permanent sod forming grasses around potential erosion sites in cropping fields. These buffered zones within croplands were classified as "other cropland" features because they could be harvested for hay and used or sold as a commodity. Not very many of these areas were evident in the 1940s, though their numbers increased in 1960s and 1990s. Much of the reduction in cropland areas was accounted for in the increases of other cropland category because of the new conservation practices.

4.3. Wilson's Creek National Battle Field

4.3.1. Classification and Image Interpretation

Nineteen different land cover categories were identified at Wilson's creek national battle field. Final land cover classification map showed major portion of the parks are covered by pasture (Figure 4-28 & 4-29). This dominant land cover occupied >50% of the total land at WICR. Oak/hickory forest and residential are the next dominant land covers. Land cover classes including oak/hickory forest, upland woodland complex, upland scrub, oak/hickory woodland, and residential showed very high temporal change in their class area compared to other classes. From 1940s to 1990s, croplands experienced a net decrease of 2,423 hectares, which indicate a major change in agricultural practices.

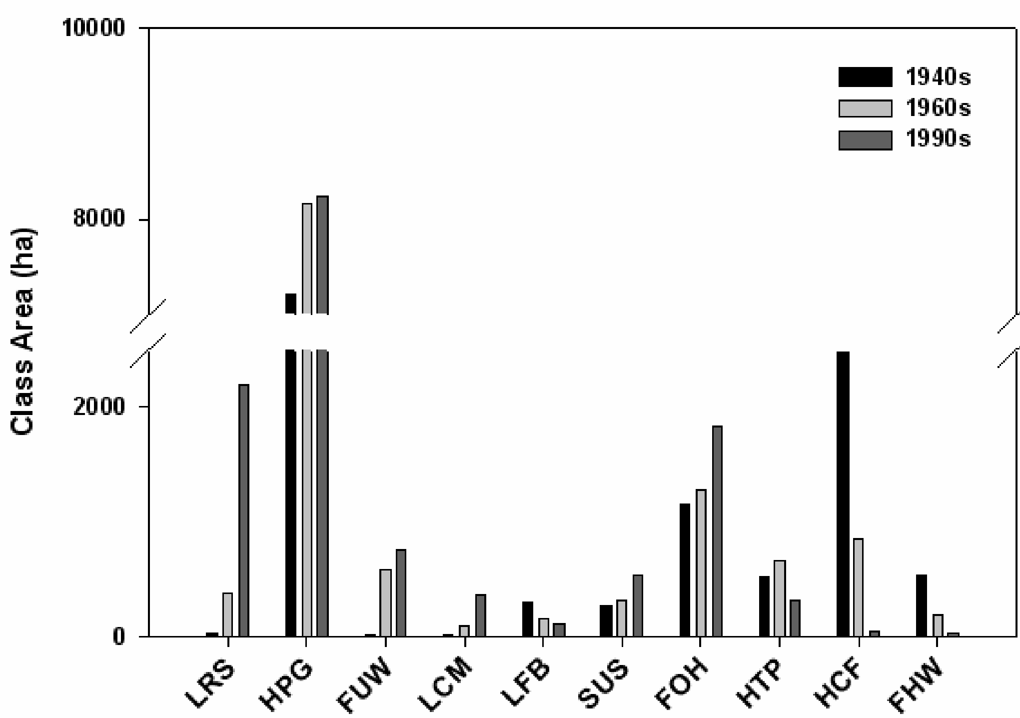


Figure 4-28: Total area of different land cover classes at WICR

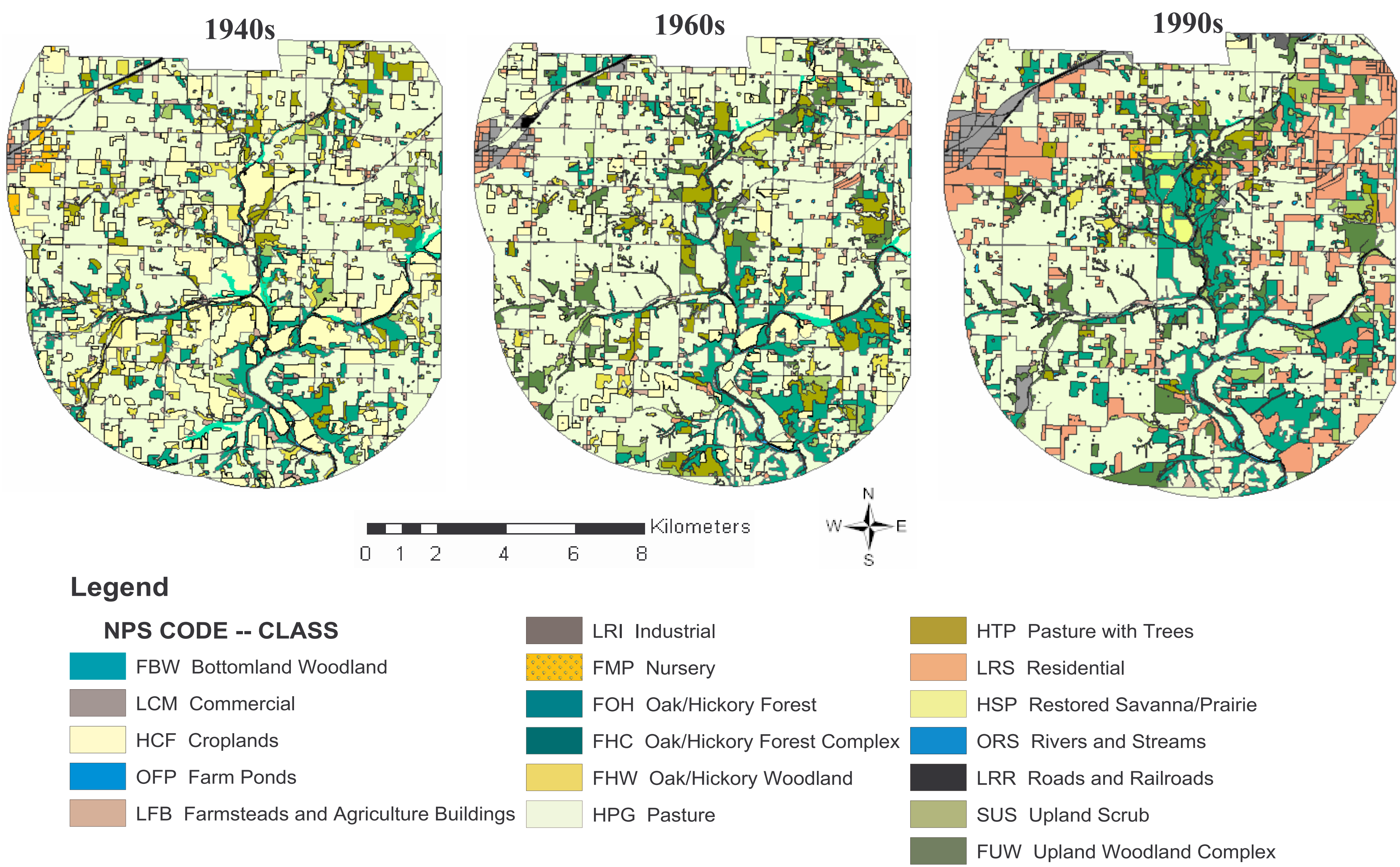


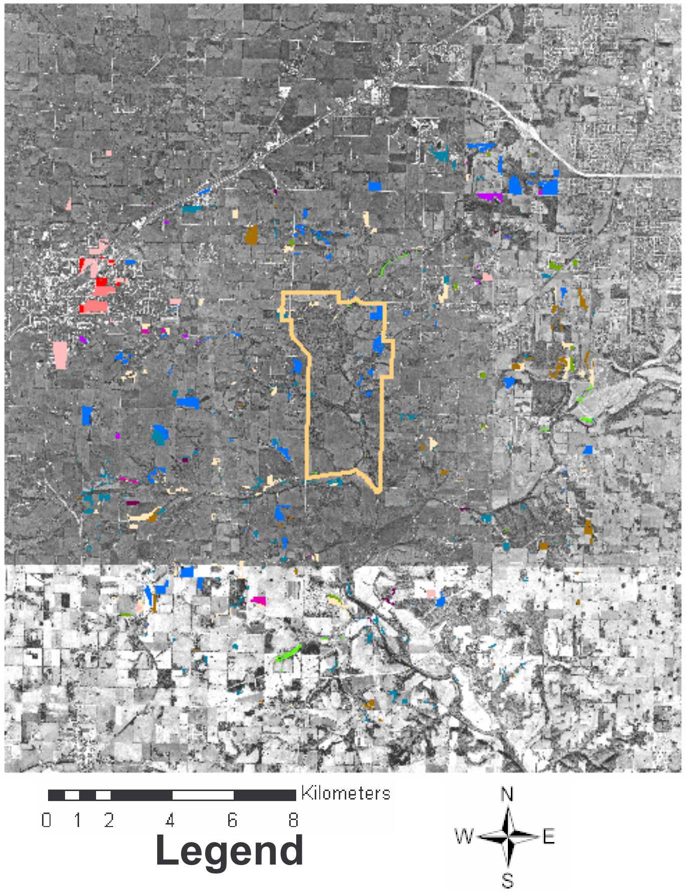
Figure 4-29: Land use/land cover classification maps of PIPE for the 1940s, 1960s, and 1990s derived from the image interpretation process

4.3.2. Change Detection

Change detection results for WICR for 1940s – 1960s show that major changes, especially with reference to natural vegetation include (a) net gain in bottomland woodland and upland woodland complex and oak/hickory forest, (b) increases in farm ponds, (c) increase in residential and pasture land and (d) a decrease of oak/hickory woodland because of thinning canopy in oak/hickory forest (Figure 4-30). Between the 1960s-1990s large areas (89 hectares) of oak/hickory woodlands had increased in canopy and were therefore, classified as oak/hickory forest in the later date. There was also a tremendous increase in residential area from 1960s to 1990s (339 hectares), which gained from natural vegetations like upland woodland complex, pasture with trees, upland scrub, oak/hickory forest, and oak/hickory woodland. Some losses of natural vegetation (e.g., oak/hickory forest and woodlands) were due the expansion of roads and railroads, as well as farmsteads and agricultural buildings in the area. There was a 34% decline (1,625 hectares) in cropland mainly due to conversion to pastureland, while some pasture in turn was re-colonized into the upland woodland (206 hectares), shrub (169 hectares) and oak/hickory forest (153 hectares) (Figure 4-31).

Overall changes in natural vegetation between 1940s - 1990s at WICR showed interchangeable shifts whereby some areas of oak/hickory forest and oak/hickory woodland woodlands had thinned-out canopies, whereas others transited from pasture in the 1940s to full growth forested areas in 1990s (Figure 4-32). A major change was the tremendous rise in the number of residential areas from 37 hectares in 1940s to nearly 2,200 hectares in the1990s, indicating the growth-effects of Springfield and Republic. Pasture experienced a net gain in each of the study periods because of large-scale conversion of croplands. These changes as well as those from “natural” land cover are depicted by different colors in the change detection matrix with the corresponding spatial locations being presented in the change detection map.

Location of changes for highlighted classes in the table



Legend

- Park Boundary
- Nursery to Pasture
- Nursery to Residential
- Nursery to Commercial
- Bottomland Woodland to Pasture
- Pasture with Trees to Pasture
- Pasture with Trees to Residential
- Upland Scrub to Pasture
- Oak/Hickory Forest to Pasture
- Oak/Hickory Forest to Residential
- Oak/Hickory Woodland to Pasture
- Oak/Hickory Woodland to Residential
- Oak/Hickory Woodland to Farmsteads

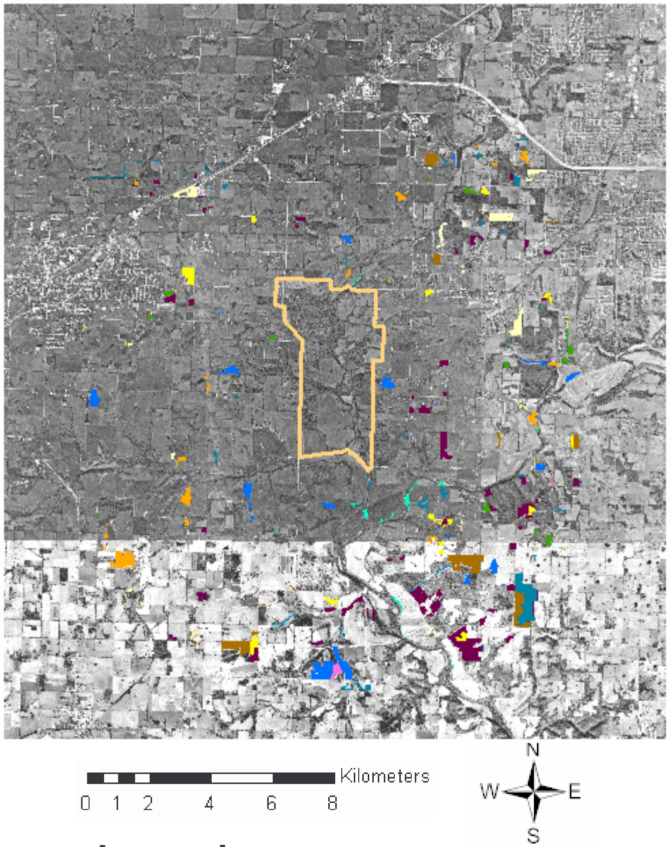
Wilson's Creek Change Detection: 1940s-1960s (hectares)

1960s (columns); 1940s (rows)

Class	FMP	FUW	FBW	HTP	HSP	HCF	HPG	LRS	LCM	LFB	LRR	OFP	ORS	SUS	FOH	FHC	FHW	LRI
FMP		3					57	20	10		1	1						
FUW				1											13			
FBW		2		15			13							6	21			
HTP		123	1			3	154	12	1	4	1	2		32	64		12	
HSP																		
HCF		14	2	47			1997	22	4	9	5	2		26	46		1	
HPG		126	3	327		536		158	52	51	30	13		155	150		58	
LRS							1		7	1								
LCM							2											
LFB		4		3			81	107	3		2			5	6			
LRR		6		2		2	32	2	5	2				2	7			
OFP		1					4											
ORS		1	2				6							1	13		1	
SUS		47					52	3							104		16	
FOH		128	9	54		4	106	9		2	1	1	14	40			70	
FHC															4			
FHW		132	7	63		1	98	15		9	1	1	2	44	136			
LRI																		

Figure 4-30: Selected land cover change for WICR (1940s-1960s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1990s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Legend

- Park Boundary
- Upland Woodland Complex to Pasture with Trees
- Upland Woodland Complex to Pasture
- Upland Woodland Complex to Residential
- Upland Woodland Complex to Farmsteads
- Pasture with Trees to Pasture
- Pasture with Trees to Residential
- Upland Scrub to Pasture
- Upland Scrub to Residential
- Upland Scrub to Commercial
- Oak/Hickory Woodland to Pasture
- Oak/Hickory Woodland to Residential

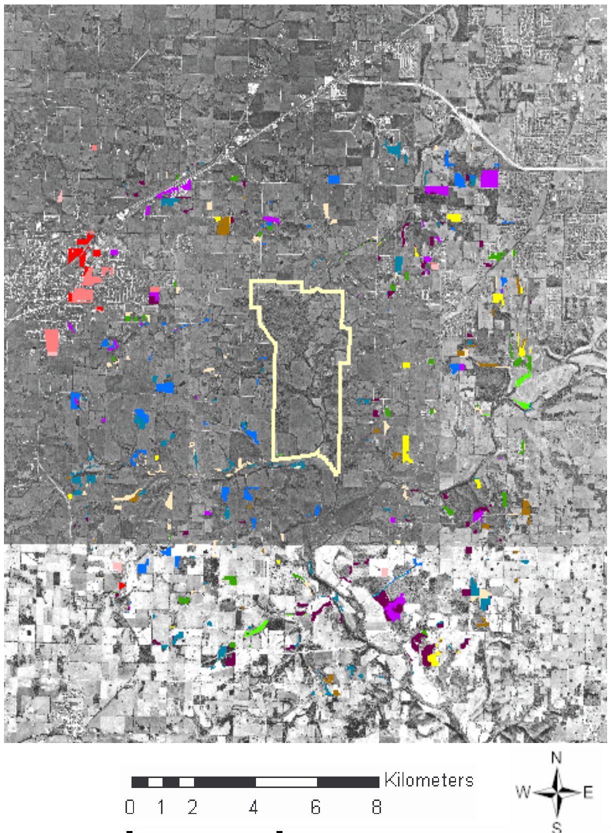
Wilson's Creek Change Detection: 1960s-1990s (hectares)

Rows: 1960s; columns: 1990s

Class	FMP	FUW	FBW	HTP	HSP	HCF	HPG	LRS	LCM	LFB	LRR	OFP	ORS	SUS	FOH	FHC	FHW	LRI
FMP																		
FUW				11			47	45	1	3	2	1	1	53	223		15	
FBW		7					4							6				
HTP		136			2		77	57		6	2			79	253		10	
HSP																		
HCF		7		1			737	68	9	2	2	1		8.5	3			12
HPG	12	206		193	91	8		1144	129	30	14	14	4	169	153		2	20
LRS		3		1			26		2	4		1		2	2			
LCM							1	11										
LFB		3					20	77	7					2	3			
LRR							6	4	11					2	1			
OFP							3	2	2						1			
ORS															1			
SUS		77					74	40	4				1		44		1	1
FOH		47		10			83	145	2	1	2	1	2	61				
FHC																		
FHW		40		15			13	23					1	2	89	5		
LRI																		

Figure 4-31: Selected land cover change for WICR (1960s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1960s-1990s), which quantify the amount of change in hectares.

Location of changes for highlighted classes in the table



Legend

Nursery to Pasture
Nursery to Residential
Nursery to Commercial
Bottomland Woodland to Pasture
Pasture with Trees to Pasture
Pasture with Trees to Residential
Upland Scrub to Pasture
Upland Scrub to Residential
Oak/Hickory Forest to Pasture
Oak/Hickory Forest to Residential
Oak/Hickory Woodland to Pasture
Oak/Hickory Woodland to Residential

Wilson's Creek Change Detection: 1940s-1990s (hectares)

1990s (columns); 1940s (rows)

Class	FMP	FUW	FBW	HTP	HSP	HCF	HPG	LRS	LCM	LFB	LRR	OFP	ORS	SUS	FOH	FHC	FHW	LRI
FMP							13	53	25		1							
FUW															6		2	
FBW		9					18							6	40			
HTP		104					93	81	7	4	1	3		58	141			6
HSP																		
HCF		83		65	39		1791	278	20	9	9	4		73	105			2
HPG	12	246		128	51	13		1128	144	39	30	19		166	409		5	25
LRS									9									
LCM																		
LFB		5		1	2		62	170	4		1			4	11			
LRR		6		1			20	11	15	1				2	10			
OFP							3	3										
ORS		1	9				4							2	4			
SUS		28		23			42	45	3						95			
FOH		115		14			126	102	5	2	2	2	14	66		2		
FHC															4			
FHW		109	3	18	1		83	53	5	3	2	1	2	55	182	3		
LRI																		

Figure 4-32: Selected land cover change for WICR (1940s-1990s). Colors on the image indicate "from-to" change categories based on "natural" vegetation and the same color is highlighted in the change detection matrix (1940s-1990s), which quantify the amount of change in hectares.

4.3.3. Landscape Metrics

Land cover classes including oak/hickory forest, upland woodland complex, upland scrub, oak/hickory woodland, and residential showed very high temporal change in their patch number, patch size and fractal dimension compared to other classes and are, therefore, examined in 3-D landscape pattern space (Table 4-4). For example, oak/hickory woodland experienced a net decrease of 149 patches over 60 years to pave way for agriculture and residential, whereas residential gained 467 patches from 1940s to 1990s.

Table 4-4: Landscape metrics of selected land cover categories at WICR

Year	No. of Patches	Mean Patch Size	Area Wt. Mean Patch Fractal Dimension
Oak/Hickory Forest			
1940s	227	10.939	1.470
1960s	180	7.896	1.149
1990s	220	6.970	1.005
Upland Woodland Complex			
1940s	3	2.360	1.197
1960s	69	8.523	1.135
1990s	113	6.685	1.022
Upland Scrub			
1940s	75	3.417	1.095
1960s	100	3.182	1.130
1990s	149	3.644	1.330
Oak/Hickory Woodland			
1940s	151	3.394	1.347
1960s	35	5.465	1.114
1990s	5	5.606	1.081
Residential			
1940s	24	1.549	1.044
1960s	235	1.601	1.055
1990s	491	4.455	1.002

The temporal shifts for oak/hickory forest indicates it has become more fragmented (number of patches and mean patch size are declining while the latter decreased more compared to the no of patches; Figure 4-33a). However, the sharp decline in mean patch fractal dimension indicates that the configuration of the boundaries of oak/hickory forests is being affected by human influences, thus regularizing the patch shapes. Depending on the land cover class adjacent to forest patches different effects may be observed in terms of ecological processes. If forest patches border upon open vegetation, such as production areas, the patch may be more susceptible to disturbances in its structure and become more regular in shape thus, decreasing the fractal dimension. Conversely, if forest patches are adjacent to succession areas, secondary re-growth may be accelerated, which will increase the fractal dimension.

By contrast, the upland woodland complex cover type has experienced considerable increase in their area. Fragmentation of this cover type is hard to observe between the 1940s-1990s because there is an increase in the number of patches and mean patch size simultaneously (Figure 4-33b). However, there is a significant decrease in fractal dimension of patches indicating increased human influence. When these data were examined in conjunction with the change detection matrix for this time period, it was noted that 246 ha of savanna/woodlands was converted to deciduous forest. This type of change can be considered a positive one for "natural vegetation" because it would imply canopy densification.

Upland scrub and oak/hickory woodland showed opposing trends. Several areas of former pastureland succeeded to upland scrub because of unrestricted growth of trees

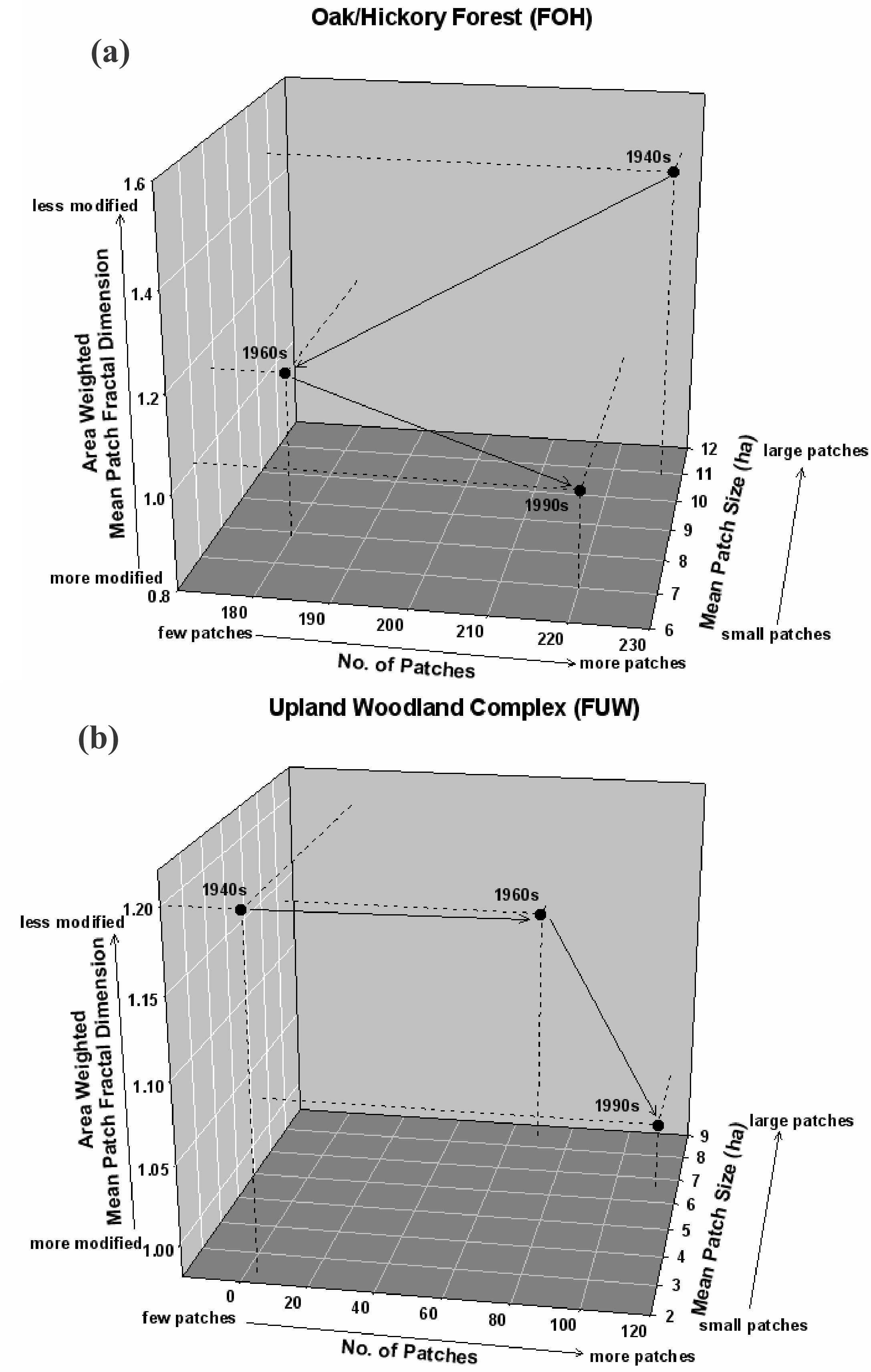


Figure 4-33: 3D landscape metrics space for (a) oak/hickory forest, and (b) upland woodland complex at WICR showing the magnitude and direction of change

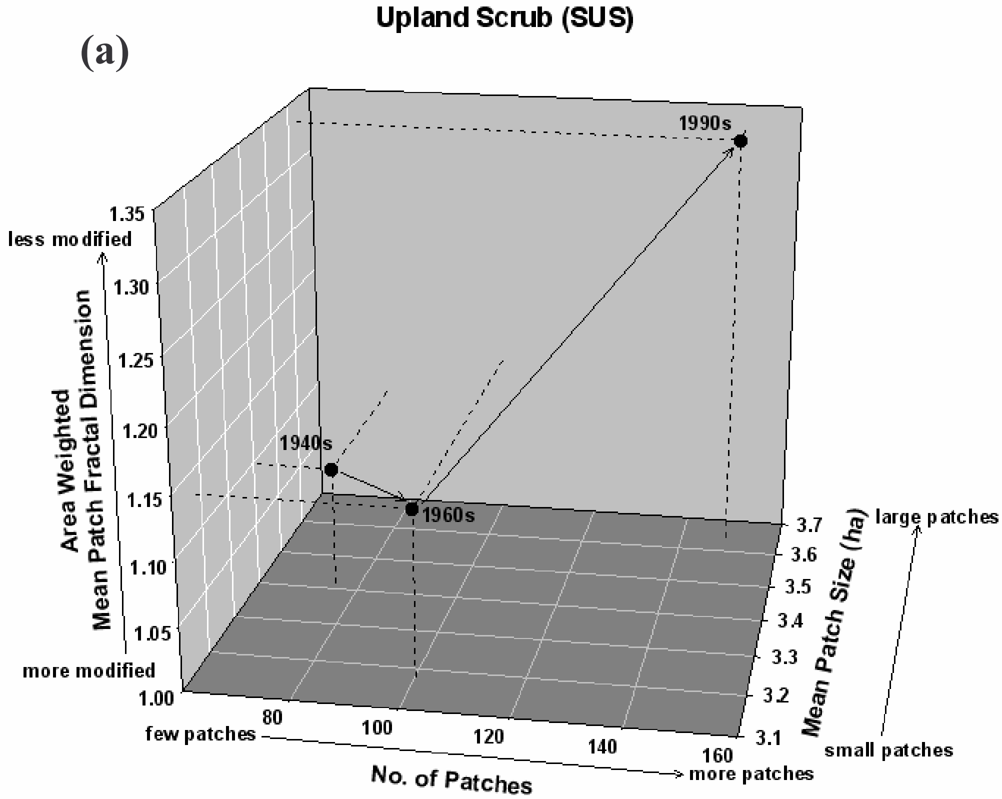
and bushes. The landscape metrics of these classes revealed an increased fractal dimension indicating that these new areas of upland scrub were irregular in shape (4-34a & b). Conversely, there was a significant decrease in the number of patches of the oak/hickory woodland. In the 1990s few patches remained with some of the areas achieving higher canopy density and being classified as oak/hickory forest (182 ha between 1940s-1990s). However, the changes of ecological concern were those where some of the oak/hickory woodland was converted to residential and pastureland.

As mentioned earlier, substantial residential growth was observed over the 60 years. The landscape metrics reveal an increase in the number of patches and mean patch size, along with a decrease in mean patch fractal dimension (Figure 4-35a). A time-sequence study of the neighborhood within a 3-mile radius of the park boundary reveals the residential migration pressure towards the park, because of the growth of nearby cities like Springfield, Republic and Battlefield (Figure 4-35b, c, & d).

4.3.4. Threat vector analysis

Threat vector analysis revealed the direction of growing residential threat within a 3-mile buffer zone from the park boundary. In the 1940s, no major threat due to residential growth was observed for the study area. Less than 10% of the land area was residential land use, and most of the segments had no residential cover (Figure 4-36a). In the 1960s, significant residential development is observed in all directions, heading towards the park boundary (Figure 4-35c). Even within a 1-mile buffer of the park, the development is evident. However, the residential proportion of land use remains low (less than 10%) in all directions except the WNW where urban development from

(a)



(b)

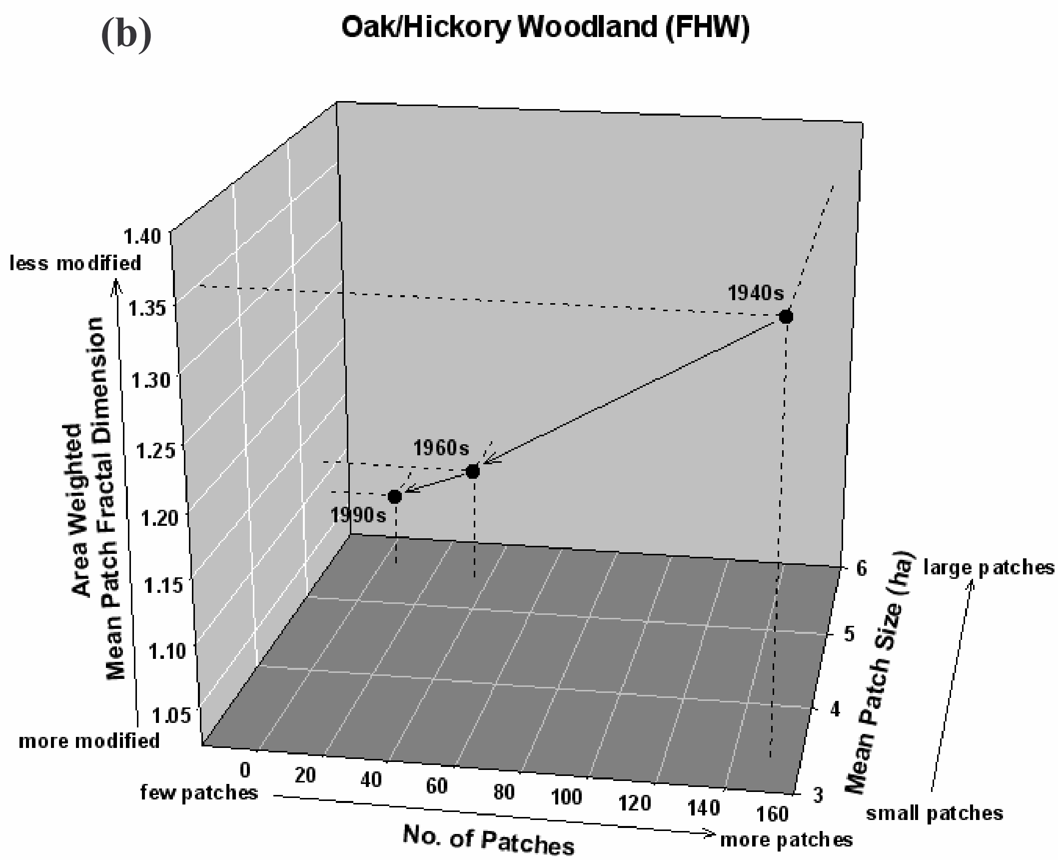


Figure 4-34: 3D landscape metrics space for (a) upland scrub, and (b) oak/hickory woodland at WICR showing the magnitude and direction of change

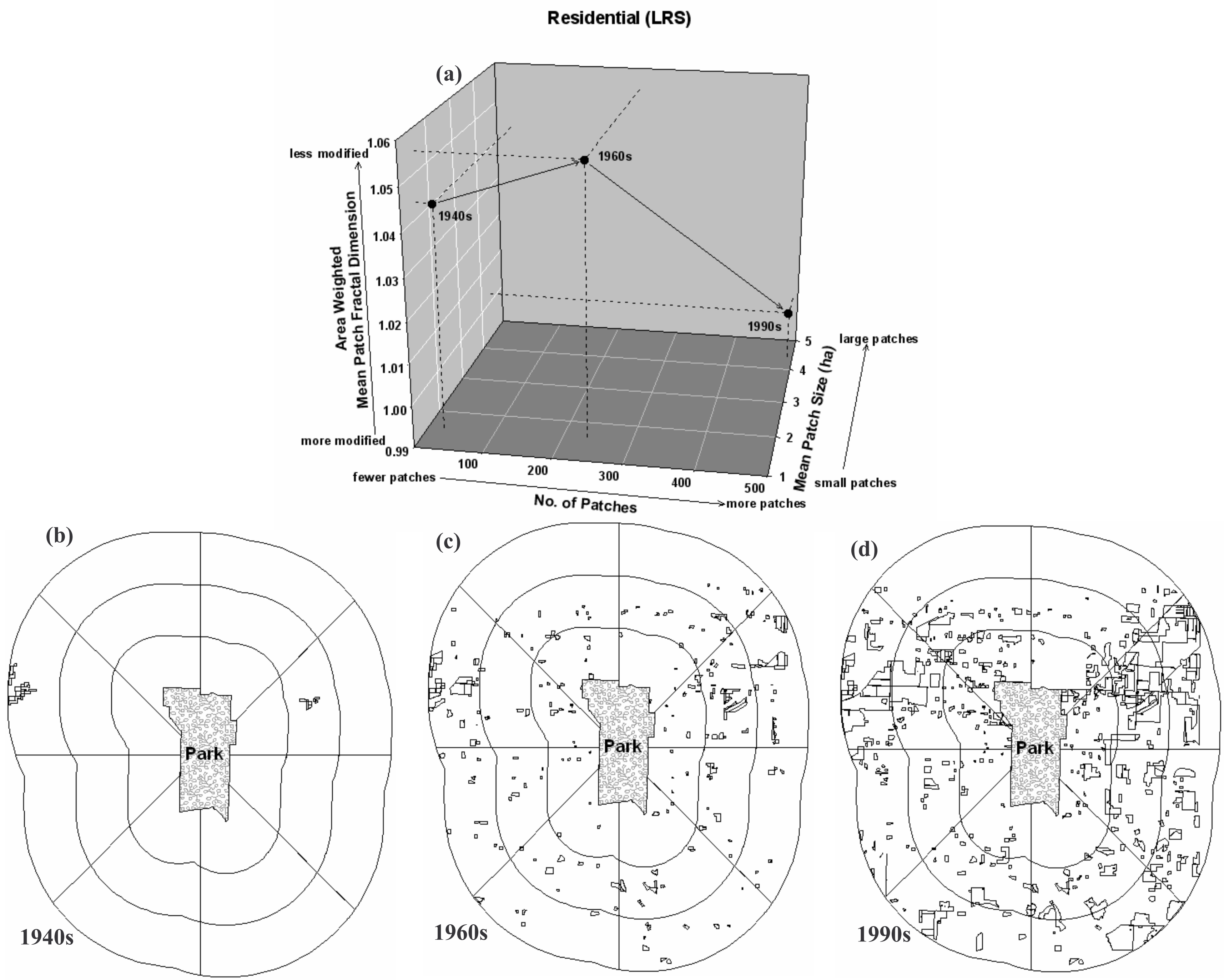


Figure 4-35: Changes in "residential" land cover shown in (a) three-dimensional landscape metric representation, and the depiction of its spatial growth within a three-mile zone from the park boundary (at 1-mile buffers) during the (b) 1940s, (c) 1960s, and (d) 1990s.

Springfield (10 miles away) begins to manifest itself within 3-miles of the park boundary (Figure 4-36b). From the interpretation of the 1990s aerial photographs and 2001 IKONOS imagery, a dramatic increase in residential areas is observed in all directions, with some of the development occurring adjacent to the park boundary (Figure 4-35d). Threat vector analysis revealed 30-50% residential areas in several segments in 1990s (Figure 4-36c). While two well demarcated threat vectors can be established from WNW and ENE directions because of the growth of Springfield and Republic, there is also an overall shift as additional segments both north and south of the park boundary begin to experience substantial developmental pressure.

4.3.5. Discussion

When evaluating change across several decades, it is important to be aware of alterations in governmental land management policy. For example, in 1936 the U.S. Department of Agriculture (USDA) introduced policy that focused on decreasing soil erosion losses from agricultural lands in the U. S. Consequently, practices such as field reshaping for terrace formation combined with contour seedbed tillage and planting are some land management strategies that were implemented to slow the rate of water runoff and decrease topsoil losses. To implement soil erosion control policy, conservation strategies were advocated by the USDA to all agricultural communities, and monetary incentives in the form of cost-share payments to land owners were offered to offset their expenses for reshaping their fields. Another facet of the soil erosion control policy emphasized monetary encouragement to land owners to create water impoundments by building earth berms in the path of precipitation runoff by providing cash assistance payments when land operators cooperated with the USDA for the design

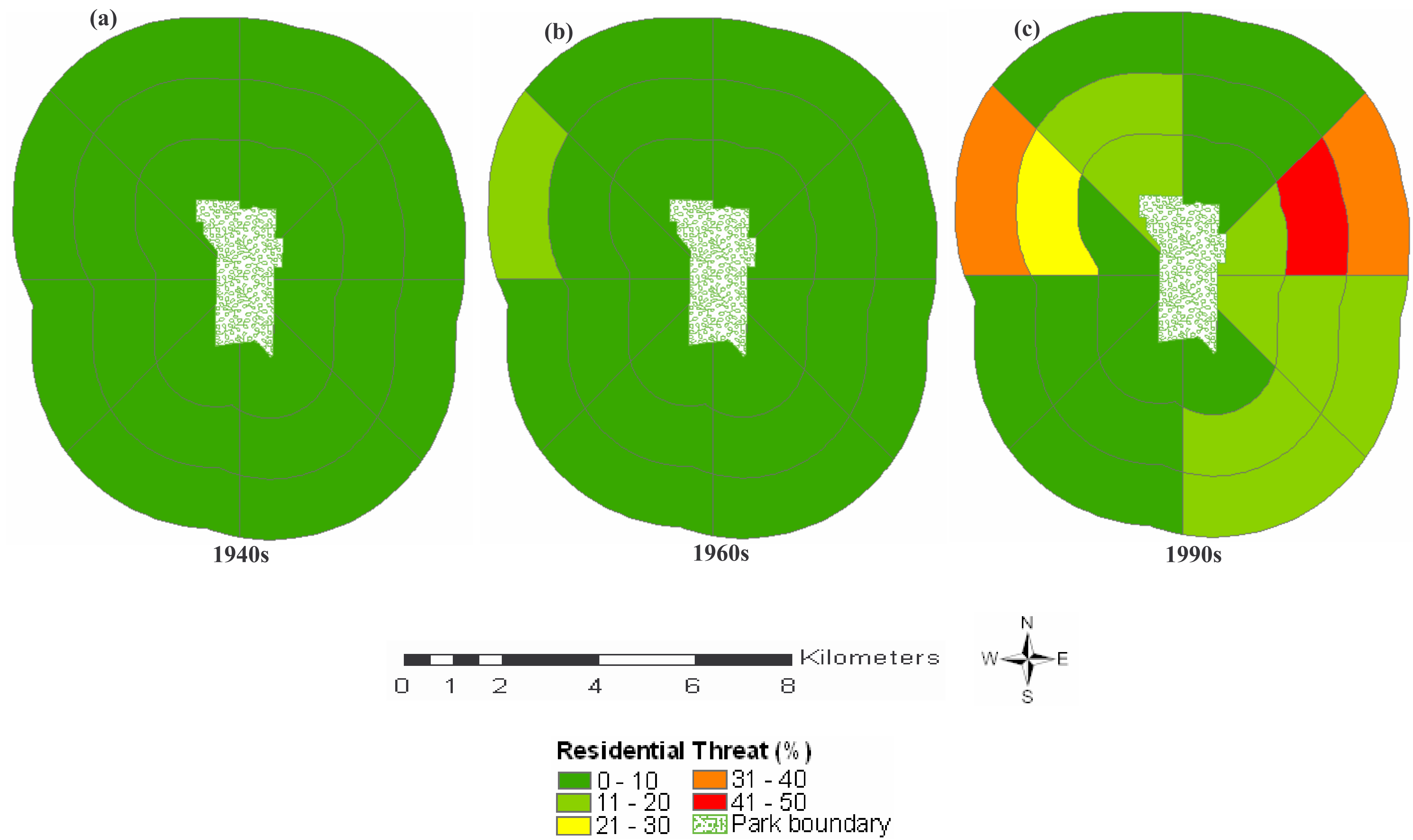


Figure 4-36: A threat vector analysis based on the ratio of residential land growth in each segment during the (a) 1940s, (b) 1960s, and (c) 1990s

phases of the projects. Consequently, large numbers of farm ponds are observed in the 1960s and 1990s at WICR.

Major landscape changes around WICR have been due to the exponential urban development and residential growth in cities near the park (NPS, 2002). Recent growth in the Springfield metropolitan area has changed the character of land use patterns in the suburban areas of Springfield, Battlefield and Republic. Large agricultural tracts increasingly are being subdivided into 10-acre residential home sites; as a result, the land area of Springfield has grown significantly. In 1961 WICR was approximately 10 miles from Springfield city limits. Now, however, metropolitan Springfield has is as close as five miles from the park, and this changing land use pattern is visible and audible from within the park boundaries. For example, transportation improvements to serve this growing suburban population are bringing higher traffic volumes and associated noise to county road ZZ and Farm Rd. 182, which respectively border the western and northern boundaries of the park.

Impact of the threat due to residential growth is being felt on the various natural, cultural, and aesthetic resources, as well as on the socio-economic environment, park access and transportation. A variety of past, present, and foreseeable actions have affected the soil, wildlife, water quality, and historic sites related to the civil war and will continue to affect the resources within the park. For example, conversion of land for residential purposes results in widespread soil disturbance and increased soil erosion associated with displacement of native vegetation. Since the 1830s, urban development has affected approximately 46,000 acres of lands within the Springfield city limit, resulting in extensive removal, rearrangement, compaction, and paving of soils.

Projected growth estimates indicate, an additional 20,000 acres of land would be developed in the Springfield region by 2020, with the consequential impacts of soil compaction, porosity, and an increase in surface runoff rates within the park (Springfield Planning and Development Department, 1998).

Projected residential development in this region is likely to increase the volume of storm water runoff discharged into Wilson’s Creek by 35 to 40% between the year 2000 and 2020. Most of the Wilson’s Creek watershed lies outside the boundary of the park in areas that had been intensively cultivated between the 1940s – 1960s, resulting in the degradation of water quality because of agricultural runoff. With the rapid pace of residential development, the storm water runoff transports urban contaminants, including petroleum products, and heavy metal into the Wilson’s Creek. Another source of past and potential contamination is Springfield’s water treatment plant, which is located upstream from the park, where sewage spills have occurred in the past and harbor a likelihood of taking place in the future (NPS, 2000). The cumulative impact of these sources of contamination has reduced populations of aquatic vertebrates, invertebrates, and occasional fish kills in Wilson’s Creek.

The conversion of land for residential use has drastically reduced the extent of native vegetation and habitats. Such development has isolated small patches of vegetation that have been transformed by fire suppression and other factors from savanna woodland dominated by scattered oaks to dense forests dominated by invasive plants such as Osage orange and honey locust (Missouri Department of Conservation, 1986). Narrow corridors along the waterways, continue to support riparian vegetation, however, the majority of wetland vegetation of the area has been destroyed by urban development (Dahl, 1990).

Residential growth has reduced the extent of native habitats available for wildlife. For example ground nesting birds and mammals are particularly sensitive to construction activities that may disrupt their reproductive and rearing cycles. Increasing mortality, competition, and predation of native wildlife have reduced their populations; and future projects such as the construction of Highway 60 bypass and urban construction of a projected additional 20,000 acres of open space by the year 2020, will continue to reduce and fragment the remaining wildlife habitat.

Unlike typical change detection procedures, this research focused on integrating the change detection results with landscape metrics. By incorporating input from PC LTEM personnel and local residents, a detailed and thorough land cover classification scheme was produced. The post classification change detection method provided information on the "from-to" conversion between land covers, while the landscape metrics explained the impact of human influence in and around the study area

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